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NASA/ESA CV-990 SPACELAB SIMULATION

FINAL REPORT

APPENDIX B – EXPERIMENT DEVELOPMENT AND PERFORMANCE

A JOINT ENDEAVOR BY NATIONAL AERONAUTICS & SPACE ADMINISTRATION AND EUROPEAN SPACE AGENCY

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16. Abstract

As a result of interest in the application of simplified techniques used to conduct airborne science missions at NASA-Ames Research Center, a joint NASA/ESA endeavor was established to conduct an extensive Spacelab simulation using the NASA CV-990 airborne laboratory. The scientific payload was selected to perform studies in upper atmospheric physics and infrared astronomy with principal investigators from France, the Netherlands, England, and several groups from the United States. Two experiment operators from Europe and two from the U.S. were selected to live aboard the aircraft along with a mission manager for a six-day period and operate the experiments in behalf of the principal scientists.

This volume, the second of five appendixes to the final report, covers the experiments flown on the Joint Mission. The experiments are described in terms of their physical arrangement in the aircraft, their scientific objectives, developmental considerations dictated by mission requirements, checkout, integration into the aircraft, and the inflight operation and performance of the experiments.

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NASA/ESA CV-990 SPACELAB SIMULATION – FINAL REPORT

APPENDIX B

EXPERIMENT DEVELOPMENT AND PERFORMANCE

INTRODUCTION

Beginning in the 1980 time period, an advanced space transportation system will be used to conduct experiments in the space environment. This system will consist of a laboratory (Spacelab) carried into orbit by the reusable Space Shuttle. The pressurized Spacelab module provides a shirtsleeve environment in which up to four payload specialists can operate experiments using the basic resources provided by the laboratory. Spacelab is being developed and constructed in Europe under the direction of the European Space Agency (ESA). The Space Shuttle Orbiter is being built by the United States under management of the National Aeronautics and Space Administration (NASA).

The Joint Mission

Similarities between the method of experiment accommodation and operations planned for Spacelab and the methods used in conducting experimentation aboard aircraft by the NASA-Ames Airborne Science Office (ASO)[1] led to the NASA/ESA Joint Mission, the sixth mission in the ASSESS (Airborne Science/Spacelab Experiment System Simulation) program. Six experiments were selected for the mission: three from Europe and three from the United States. The simulation mission took place at the NASA-Ames Research Center, Moffett Field, California, USA, between April 30 and June 24, 1975.

Spacelab payload manpower will be limited to a maximum of four, which means that payload specialists often will be acting as proxy operators for principal investigators' (PI) experiments. To test the concept of proxy operation, four experiment operators (EOs) were selected and trained on the six experiments. During the simulation period, the EOs performed all experiment operations, including data taking, normal servicing, and minor repairs. For the entire simulation period, the four EOs and the Mission Manager were confined to the aircraft and an adjacent sleeping area. All communications with the outside world during the simulation period were handled by communications links (audio and video) simulating those planned for Spacelab. Scientific data were taken on all flights.

Mission preparations, operations, and results are documented in an executive summary, a final report, and five appendixes (see refs. 1-4). Information for these documents was gathered from several sources: the records of a team of observers who flew on all flights and observed mission activities in

[1] Now designated the Medium Altitude Missions Branch.

detail, mission operational records, mission planning documentation, information prepared by the PIs and EOs, an extensive debriefing following the simulation period, and individual interviews with mission participants.

Mission Objectives and Guidelines

The overall objective of the Joint ASSESS Mission was to evaluate a simplified management and implementation concept for conducting Spacelab-like experiment operations. The following were subordinate mission objectives:

1. To experience involvement in international cooperative payload activities

2. To evaluate experiment design approaches for Spacelab experiments

3. To determine the impact of operational requirements and procedures on Spacelab design

4. To evaluate payload and mission operations

5. To assess techniques for smooth integration of experiments and equipment

6. To analyze factors affecting selection and training of payload specialists, particularly in proxy experiment operation.

The Joint ASSESS Mission also served to encourage the development of a cadre of potential Spacelab experimenters. The Mission did not address physiological or psychological factors.

The mission guidelines were designed to ensure a high degree of realistic simulation given the capabilities of the CV-990 aircraft, ASO practices, and the requirements for Spacelab as stated about one year before the ASSESS mission. The complete guidelines are provided in the Mission Operating Plan (Appendix E, ref. 4) and are summarized below:

1. Authentic science to be performed

2. Six basic experiments to be operated (three European, three U.S.)

3. Ames ASO practices to be used as starting point for mission planning and execution

4. Participation of PIs in overall mission to be maximized

5. Four EOs (two European, two U.S.) to operate experiments in proxy role (i.e., on behalf of the PIs)

6. Simulation period to cover 5 days with a data flight each 24-hr period (experiments operated by EOs), with EOs and the Mission Manager confined to vehicle and living quarters

7. Unconstrained flights to be conducted for 2 weeks following the simulation period (experiments operated by PIs)

8. All supporting equipment, tools, and spare parts to be carried on board

9. Spacelab subsystems to be simulated where possible

10. Use of experiment support equipment to be shared

11. Communication to be limited to one video downlink, two 2-way voice links.

Mission Management

Basic guidance for the mission was provided by the seven-member Mission Planning Group (MPG), which comprised representatives from both NASA and ESA Headquarters organizations and from the Marshall, Johnson, and Ames NASA centers. Six planning sessions were held between May 1974 and May 1975 at which the MPG set the schedule, ratified the selection of experiments and EOs, developed the mission guidelines, and checked the status of the mission at all critical points.

The Mission Manager, from the ASO, was the single point of contact for all negotiations, decisions, and assistance in carrying out the mission from inception to completion. With the aid of one full-time assistant, he implemented the directives of the MPG; communicated with the PIs relative to their mission responsibilities; and handled all detailed planning of experiment integration, flight operations, and support activities.

This volume, the second of five appendixes to the final report, covers the experiments flown on the Joint Mission. The experiments are described in terms of their physical arrangement in the aircraft, their scientific objectives, developmental considerations dictated by mission requirements, checkout, integration into the aircraft, and the inflight operation and performance of the experiments.

THE EXPERIMENTS

Experiments flown on the Joint ASSESS Mission are described in this section. Particular attention is given to their arrangement in the aircraft to illustrate the physical environment in which the experiment operators had to work (fig. B-1). The scientific objectives given for each experiment are generally taken directly from the experimenters' proposals. Each experiment is described separately, although it must be remembered that two groups of three experiments each were operated together by single EOs. The Queen Mary College, University of Southampton, and University of New Mexico experiments at the forward end of the cabin were operated by one EO, and the Jet Propulsion Laboratory, University of Colorado, and University of Alaska experiments located toward the rear of the cabin were operated by the second EO. The Meudon telescope, located in the left side overwing escape hatch in combination with either the University of Groningen or the Ames detector, was operated by a third EO who had no other responsibilities for experiments.

Experiments are discussed in the order of their placement in the aircraft from front to rear as follows: (1) Queen Mary College, upper atmosphere radiometry; (2) University of Southampton, survey of OH airglow clouds; (3) University of New Mexico, photography and photometry of OH airglow clouds; (4) Observatoire de Meudon/University of Groningen, mapping of dark clouds and HII regions; (5) Ames Research Center, near-IR observations of late type stars; (6) Jet Propulsion Laboratory, UV and visible spectrum observations of Venus and the upper atmosphere; (7) University of Colorado, UV spectroscopic observations of Venus, Mars, and selected stars; and (8) University of Alaska, UV studies of planetary atmospheres.[2]

Much of the material in this section was prepared by the EOs and the PIs themselves as part of the mission record. Experimenters were formally requested to tabulate information about their experiments, experiment development, and testing. Not all complied with this request, and therefore the level of coverage is not uniform for all experiments. The development and testing activities covered in this section include those performed at experimenters' home laboratories. Additional development and testing performed at Ames during the checkout and integration period are discussed in the next two sections.

Queen Mary College

This experiment, titled Absolute Spectrometric Radiometry of the Upper Atmosphere (and Development of Cosmic Background Radiometry), was sponsored by the Department of Physics, Queen Mary College, University of London, London, England. Its scientific objective was to measure the thermal emission

[2]At the time of selection, experiments (6), (7) and (8) were proposed as a single, three-part experiment by one PI. Subsequently, they were developed by the separate research groups, with overall coordination by the proposing PI.

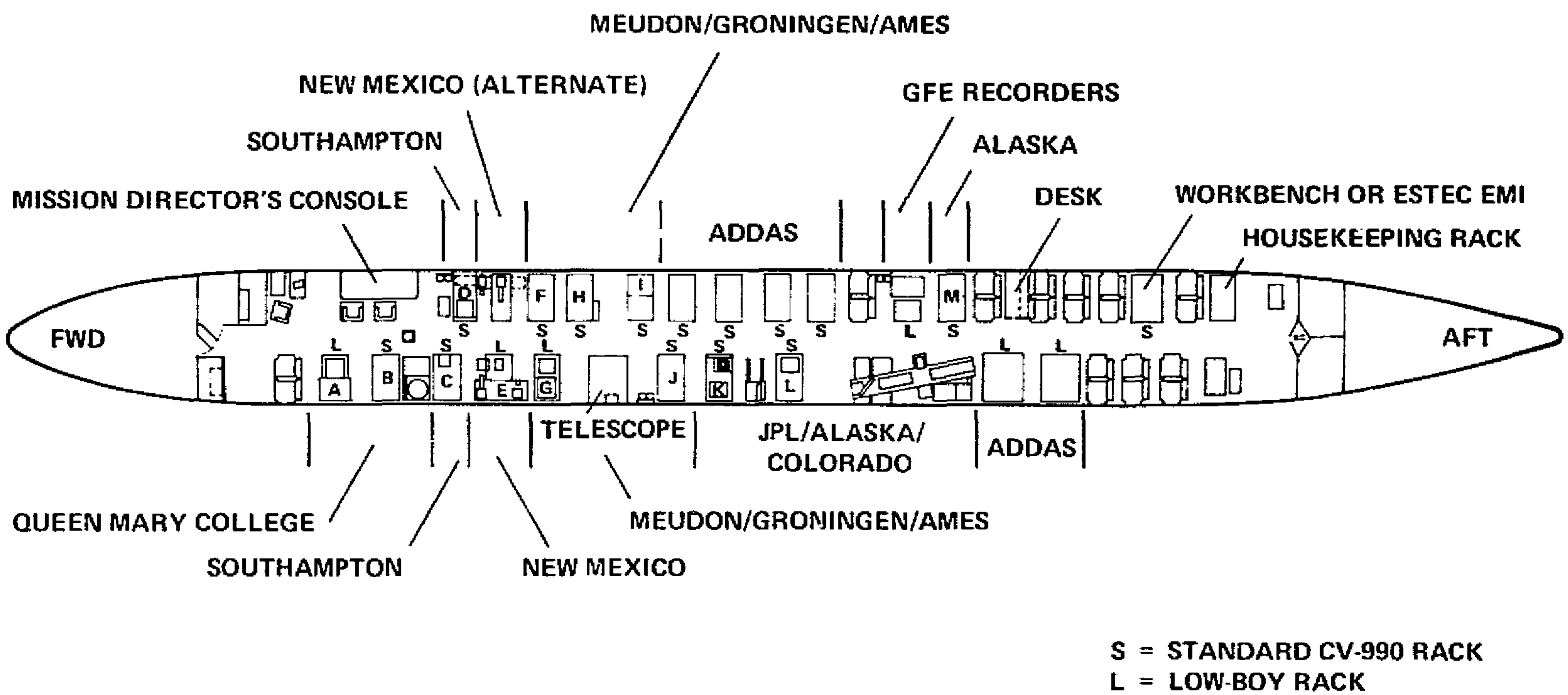


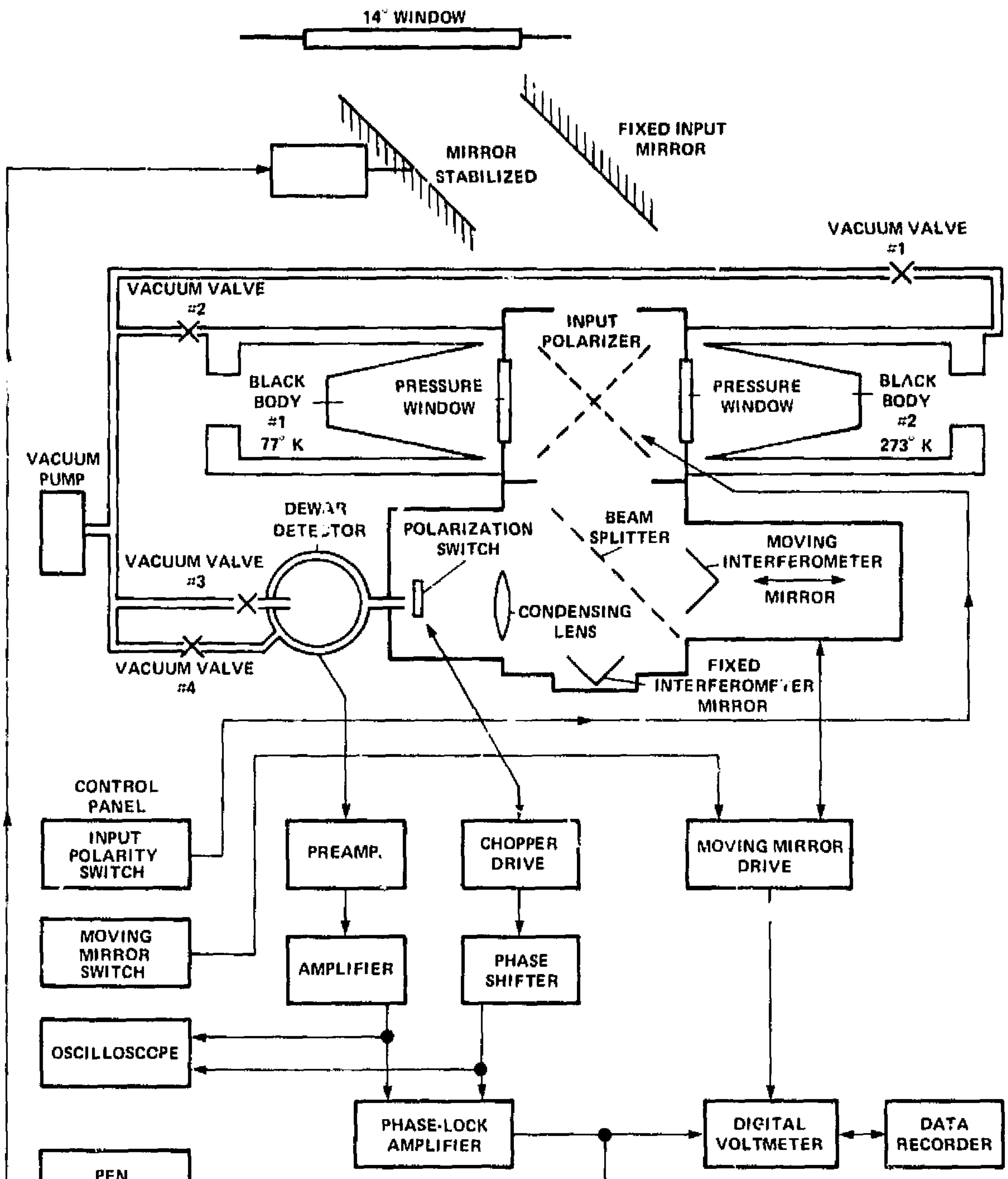
Figure B-1.- Arrangement of experiments in aircraft cabin.

spectrum of the earth's atmosphere over the 5 to 250-cm^{-1} range using a polarizing interferometer. The intensity measurements were to be absolute and with a maximum resolution of 0.025 cm^{-1}. Spectra of the atmospheric emission were recorded as a function of the elevation angle over the range of -5° to 15° (limb-scanning), and information was obtained on absolute spectral radiance and atmospheric composition as a function of altitude.

Basic instrumentation- Figure B-2 is a diagram of the experiment. The central element is a Michelson interferometer, shown in the upper portion of the figure. Through the use of polarizing optics, the instrument simultaneously passes two beams of radiation, one emitted by molecules in the earth's atmosphere and one emitted by a calibrated reference source — the 77 K or 273 K black body. The two polarizations are established by the parallel-wire input polarizer, which polarizes in one plane in transmission and in a plane perpendicular from the first in reflection (from one of the reference sources). The two beams then pass through the interferometer and are alternately incident on the detector (a germanium bolometer at about 2 K) due to the action of a rotating polarization switch, which intercepts the beam. The detected signal is demodulated, and the interferogram results from recording the demodulated signal as a function of the moving mirror position. The true spectrum results from the Fourier transform of the interferogram. The input optics are stabilized for aircraft roll, by a mirror controlled by a signal from the CV-990 inertial navigation system (INS), to partially eliminate from the computed spectra the spurious features that result from fluctuating optical path lengths in the earth's atmosphere.

Equipment configuration- All components, except a vacuum pump and a liquid nitrogen storage dewar (both GFE), were mounted in or on two racks shown in figures B-3 and B-4. Component specifications are given in table B-1. The low boy (rack A) was used primarily as a platform to position the interferometer adjacent to a window; all other components were mounted in or on rack B. Some areas of the rack were unsuitable for mounting because of components protruding from the opposite face; where space permitted, such areas were used for storage. Switches and controls were distributed over the whole of the face of rack B, and displays such as the stripchart recorder (2), where the EO was expected to hand log experiment parameters, were kept to the top of the rack. Five backup components (8, 9, 10, 12, and 15) were mounted and ready for immediate use. The tape recorder (12) and computer (15) were provided in case of catastrophic failure to the ADDAS. ADDAS failures were frequent but only of relatively short duration, so the backup instruments were not used. Backup components 8, 9, and 10 were not needed either.

Experiment development and preparation- Table B-2 summarizes the development history of the QMC experiment. Table B-3 details experiment modifications needed for the Joint Mission. Table B-4 gives the components design and construction schedule, and table B-5 outlines experiment testing in preparation for the mission. The tables were prepared by the ESA EOs in April 1975 and cover work at Queen Mary College prior to equipment shipment to Ames via ESTEC.



1. Input polarizer: two positions, parallel-wire-grid type with wires perpendicular to plane of paper
2. Beamsplitter: parallel-wire type with wires making 45° angle to plane of paper
3. Moving interferometer mirror: cube corner type (retroreflector)
4. Fixed interferometer mirror: cube corner type
5. Polarization switch: rotates on optic axis; passes input or BB light alternately
6. Detector: doped germanium bolometer; 2° K

Figure B-2.- Block diagram of the QMC interferometer.

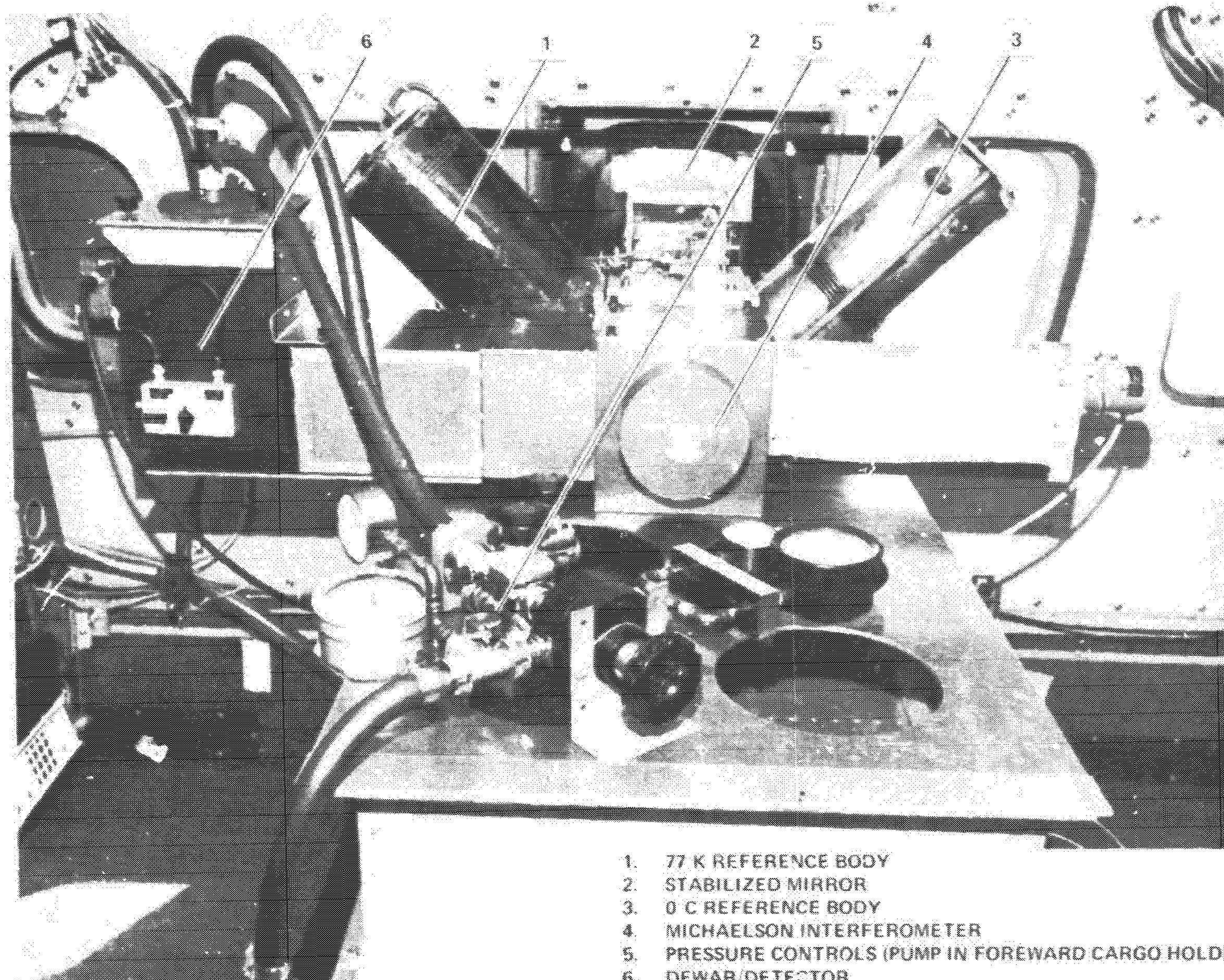


Figure B-3.- QMC equipment configuration rack A.

1. DIGITAL VOLTMETER
2. STRIPCHART RECORDER
3. OSCILLOSCOPE (DUAL BEAM)
4. STABILIZED MIRROR AND INPUT POLARIZER CONTROL/GENERAL POWER
5. AC AMPLIFIER
6. PHASE SENSITIVE DETECTOR
7. REFERENCE WAVEFORM (DERIVED FROM CHOPPED SIGNAL)
8. }
9. } BACKUP FOR 5, 6, 7, RESPECTIVELY
10. }
11. CHOPPER CONTROL
12. DUAL CASSETTE TAPE RECORDER (ADDAS BACKUP)
13. A/D CONVERTER AND DISPLAY
14. INTERFEROMETER CONTROL
15. COMPUTER (ADDAS BACKUP)

Figure B-4.— QMC equipment configuration rack B.

TABLE B-1.- QMC COMPONENT INFORMATION

Component function	Construction	Dimensions, cm			Power			Weight, kg
		H	W	D	V	A	W	
Interferometer	Modified FS-720	20	20	20	--	--	--	40
High-resolution mirror drive	Custom	16	50	16				16
Stabilized mirror drive	Custom	16	50	16				16
Beam-switch box	Custom	20	18	18				8
Stabilized mirror	Custom	28	15	13				3.5
Black body 1	Custom	25	16	33				15
Black body 2	Custom	25	16	33				17
Detector cryostat	Off-the-shelf	35	18	18				6
Detector and preamplifier	Investigator-built	--	[illegible]	--				--
Pressure controller and valves	Off-the-shelf	15	15	15				3.5
Base plate	Custom	4	63	115				9
Amplifiers (2)	---	8	22	27	115	Total estimated 5 A	Total estimated 575 W	
Phase-lock amplifiers (2)	Off-the-shelf	8	22	27	115			16
Reference wave form	---	8	22	27	115			
Control panel	Custom	18	48	29	26 and 115			4.5
Oscilloscope	Off-the-shelf	12	48	38	115			11
Strip-chart recorder	Off-the-shelf	20	45	30	115			16
Chopper and drive support	Custom	18	48	30	115			10.5
High-resolution drive support	Modified	18	48	30	115			11
A/D converter	Off-the-shelf	13	48	25	115			8
Computer	Off-the-shelf	21	48	48	115			32
Cassette recorder	Off-the-shelf	18	48	30	115			8
						Total		251.0

TABLE B-2.- QMC EXPERIMENT DEVELOPMENT HISTORY

Experiment/component	Initial development date	Earlier modifications	Modifications for the joint mission	Time involved, man-years[a]
Black-body calibrators	April 1974		Reconstruct for cryogenic reasons	0.2
Polarizing interferometer	1970	Continuous development	Increase mirror movement improve polarizers	0.7
Output optics	Feb. 1975		New	0.3
Detector and detector cryostat	1972	Continuous development	Improved crystal stabilizer for temperature	0.1
Detector electronics	1972	Continuous development	Quieter supplies; more stable phase-shifter	0.05
Display and data acquisition	Jan. 1975		Faster sampling ADC give extended range and more reliability; software developed for Fourier transformation at Ames	0.8
Input optics and stabilized mirror	Feb. 1973		Larger aperture	0.2
Control box and earthing and other cabling	March 1974		New	0.2
			Total	2.55

There has been no previous flight of this absolute spectrometric radiometer system. However, an experiment with similar objectives was conducted (without NASA/ESA support) from a mountain site in the Swiss Alps (Gornergrat) in September 1974. Estimates of time and the experiment modifications cited refer to developments following that expedition.

TABLE B-3.- QMC EXPERIMENT MODIFICATIONS FOR THE JOINT MISSION

Black-body calibrators
1. Thorough vacuum leak test; repairs.
2. Test new ceramic surface plates at low and high temperatures.

Polarizing interferometer
1. Design and construct new precision mirror drive to give very high resolution; 25-cm movement, 2-μm precision.
2. Develop methods for lithographic reproduction of polarizers.

Output optics
1. Design output optical box.
2. Design and make polarizing chopper (earlier chopper injected noise signal via optical input).

Detector and detector cryostat
1. Obtain and test pressure controller to stabilize temperature.
2. Assemble reserve detector and cryostat.
3. Improve light-pipe collector in cryostat.

Detector electronics
1. Test batteries for drift and fluctuation problems.
2. Replace phase-shift panel to eliminate instability.

Display and acquisition
1. Design and assemble fast acquisition system to cope with high-resolution and fast-scan interferograms.
2. Develop software for Fourier transforms.

Input optics
1. Redesign stabilized mirror system to give larger aperture.
2. Construct.

Control box and earthing
1. Design and construct central control panel for experiment.
2. Review thoroughly earthing systems to ESRO requirements.
3. Re-cable to give standard interconnections.

TABLE B-4.- QMC COMPONENTS DESIGN AND CONSTRUCTION SCHEDULE

Sept.-Dec. 1974
Black-body sources: Ceramic surfaces made and tested; cracked on cooling and required soldering cavity so as to be vacuum-tight
Preliminary discussions on design of high-resolution mirror drive, data-acquisition system, and input-optics
Pressure controller acquired and tested: satisfactory
January 1975
Tests of transmission and of thermocouple mounting for aircraft window; information to the Mission Manager
Racks received from Ames
Vacuum-testing of cooled black body, found unsatisfactory, leaks incurable
Designs of input optics and high-resolution mirror drive completed and construction initiated
ADC ordered, parts received, and assembly completed
February 1975
Baseplate machined for mounting on rack
Input optics completed
Cooled black body: changed from vacuum-cryogenics to power insulation, partially satisfactory
Chopper unit constructed
Filter acquired
Software written for data-acquisition system
DVM assembled
Control panel assembled
March 1975
Polarizing grids wound
System assembled
1-2 weeks lost through illness and absences on other business
Paperwork for EO training prepared
Discussion of scientific objectives with EOs, and Experiment Readiness Review
April 1975
System test runs (without liquid-nitrogen black body and data acquisition)
Disturbance of detector by vibrations investigated; chopper noise eliminated
EO training
Tasks remaining to be done as of April 4th
Complete liquid-nitrogen black body
Test data-acquisition system
Dispatch equipment to ESTEC for consolidation and shipment to Ames

TABLE B-5.- QMC HOME-BASE TESTING

Experiment component	Date	Type of test	Time tested	Test equipment used	Problem or highlights
Black-body calibrators	Apr. 8	Cooling and check on output stability		Full system	Not yet completed
Polarizing interferometer	Apr. 2	Record interferograms of cold-body source		Stripchart output Cooled detector	Some vibration sensitivity
Output optics	Apr. 1	Run chopper and check detector noise		Cooled detector	Noise eliminated
Detector and cryostat	March	Signal-to-noise ratio for standard signal			Satisfactory
Display and data acquisition	Apr. 8	Fidelity and reproducibility of signal recording		Signal generator and computer	Not yet completed
Input optics and stabilized mirror	March 20	Mirror movement under simulated INS signal		INS signal simulator	Stronger spring required or beam-switch mirror
Control box	March 20				Satisfactory
High-resolution drive	Apr. 10	Record interferogram and Fourier transform		Full system and computer	Not yet completed

Staffing and support requirements- Three workers were directly engaged in the project most of the time: a technician, an experienced experimental research assistant, and a competent experimenter and good physicist.[3] Previous experience with the interferometer at a ground site (Gornergrat in the Swiss Alps) suggested this level of staffing which proved sufficient for the Joint Mission. The PI, who exercised a management role, arranged for an adequate level of electronics, mechanical, and computer support, which was obtained almost entirely (70 percent) from within Queen Mary College (table B-6).

In this case, because most of the instrumentation existed already, preparations for the Joint Mission were handled expeditiously and costs were kept down. It is doubtful whether an "all in-house" project could be so readily completed for Spacelab applications.

TABLE B-6.- QMC INTERNAL AND EXTERNAL SUPPORT

Support organization	Type	Contributions, man-years	Percent of total
Queen Mary College London, Physics Department	Scientific	0.5	70
	Experimental technician support	2.0	
	Electronics shop, design and test	.2	
	Optical/lithographics shop	.2	
	Mechanic shop	.4	
National Physical Laboratory, London	Scientific	.2	7
	Design	.05	
	Machine shop	.1	
Falco Ltd.	Data-acquisition system support	.5	10
Pentagram Software Products Ltd.	Computer software	.5	13
Laurence Morris Ltd.	Machine shop	.1	
	Totals	4.75	100

University of Southampton

This experiment, titled Survey of OH Airglow Clouds, was sponsored by the Department of Physics, University of Southampton, Southampton, England. The scientific objective was to survey the geographical distribution, frequency of

[3]In accord with the U.S. Privacy Act of 1974, all names of mission participants have been omitted from the text.

occurrence, and extent of OH airglow clouds, by means of an image isocon TV system. A second, unrelated objective was to examine the use of the instrumentation in counting sporadic meteors.

The primary source of infrared airglow arises from the rotation-vibration bands of the OH molecule (ref. 5). Recently, Petersen and Kieffaber (ref. 6) have published photographs of the night sky in Arizona taken with high-speed infrared film (emulsion cutoff, 0.9 μm). The photographs show bright cloudlike structures of variable intensity, which move with velocities of some tens of meters/second. They have been identified as patches of OH airglow and occur at altitudes of about 100 km. An aircraft survey has the great advantage that problems in identification of meteorological clouds are eliminated. Apart from the intrinsic interest in a survey of OH airglow, the information obtained would prove most useful in planning a program of ground-based observations of OH clouds designed to study upper atmosphere winds on a more continuous basis than is possible with chemical-release experiments.

Basic instrumentation- Basic signal detection was provided by an image isocon TV camera limited to the region between 650 nm and 950 nm. The desired bandpass was obtained from a 650-nm filter and the inherent cutoff of the sensitivity of the tube. The camera control was modified to permit integration of the signal with readout at several selectable frame rates lower than that of a normal TV system. A standard video tape recorder was used, with its controls modified to match the slow frame rate of the video signal. A monitor was provided to display the integrated signal on a continuous basis.

The TV system with a normal lens has a field of view (FOV) of 30°. To obtain a more general view, an all-sky camera with a 180° lens was fitted to a zenith window in the CV-990. The camera used high-speed infrared film with automatically controlled exposures of 5 to 10 minutes. An infrared photometer was also provided to permit calibration of the TV signal.

Block diagrams of the TV system and the photometer are given in figures B-5 and B-6, respectively.

Equipment configuration- As with the QMC experiment, one rack held almost all of the Southampton electronics while a second was used primarily as a platform to position a sensing component near a window. The rack supported component was the TV camera; the other sensing components, the photometer and the 180° FOV camera, were positioned near windows by attaching to the window hard-points. The arrangement is shown in figure B-7. The somewhat awkward position of the lock-in amplifier in the rack (C) was determined by rack-overturn moment considerations. Component placement in the electronics rack (D, fig. B-8) is also awkward. The control electronics of the TV camera (2) are mounted well inside the outboard bay, so that to see the control knobs well (2' in fig. B-8) the operator had to stoop and insert his head somewhat into the open portion of the bay. The situation was improved by bringing the most frequently adjusted controls out to a box (10) mounted on

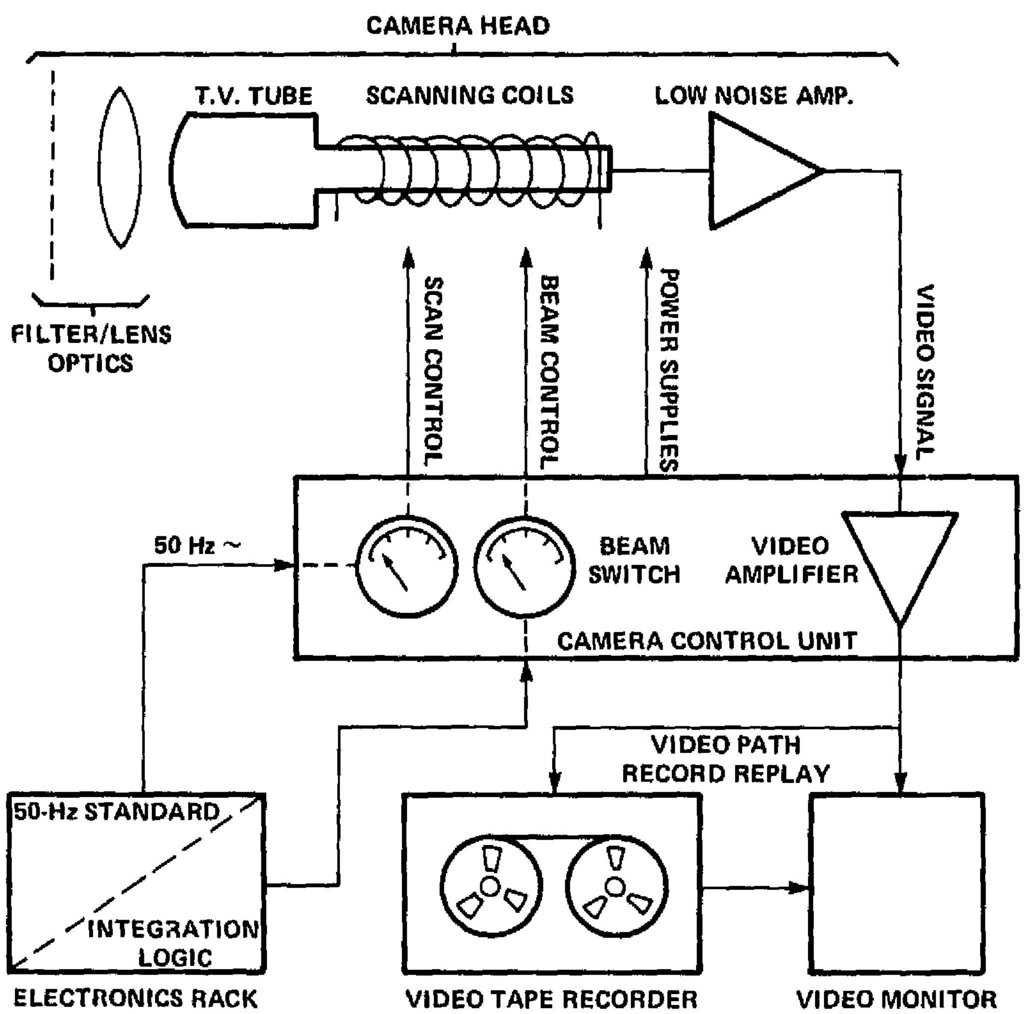


Figure B-5.- Block diagram of the Southampton television system.

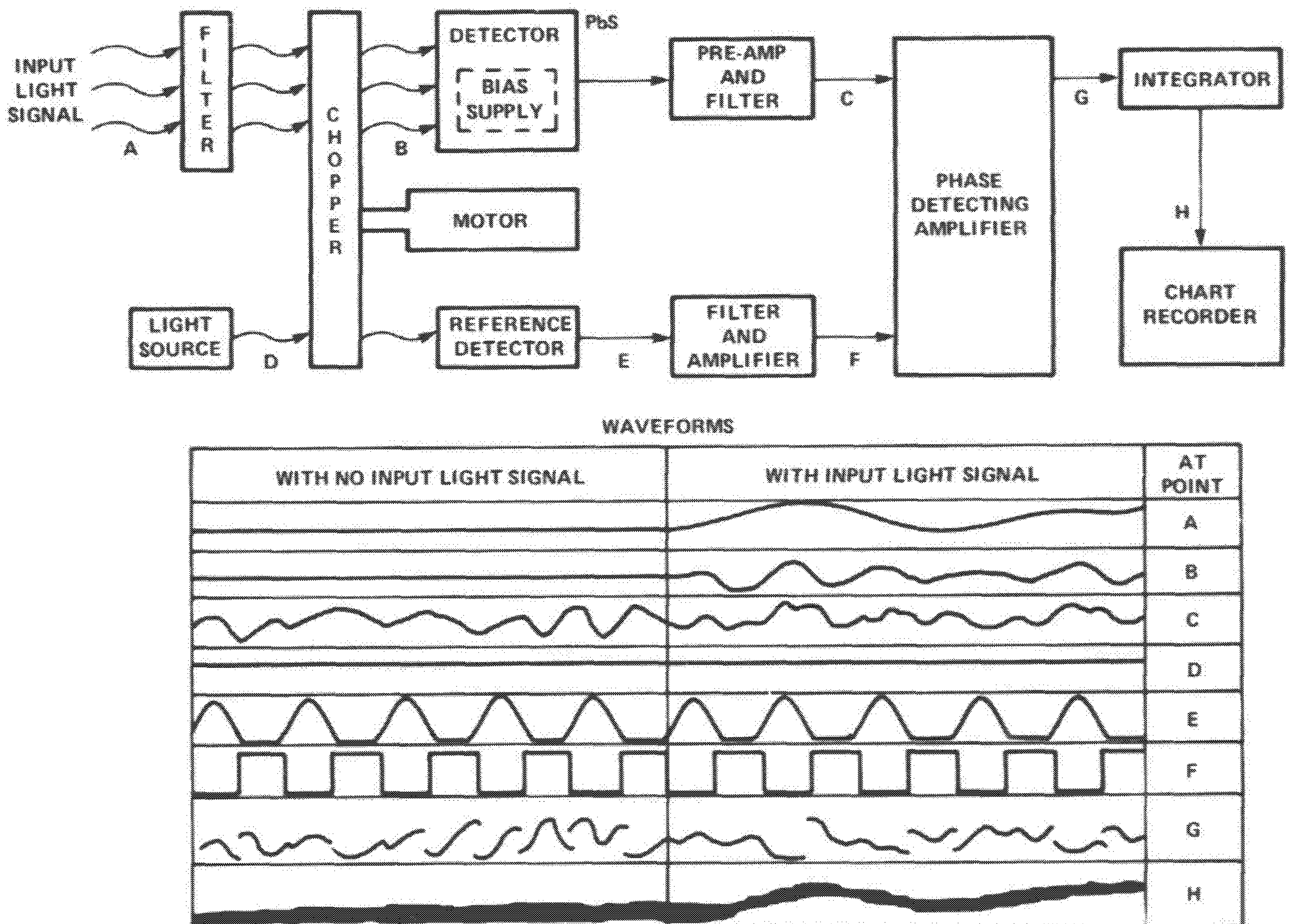


Figure B-6.- Block diagram of the Sou.hampton infrared photometer.

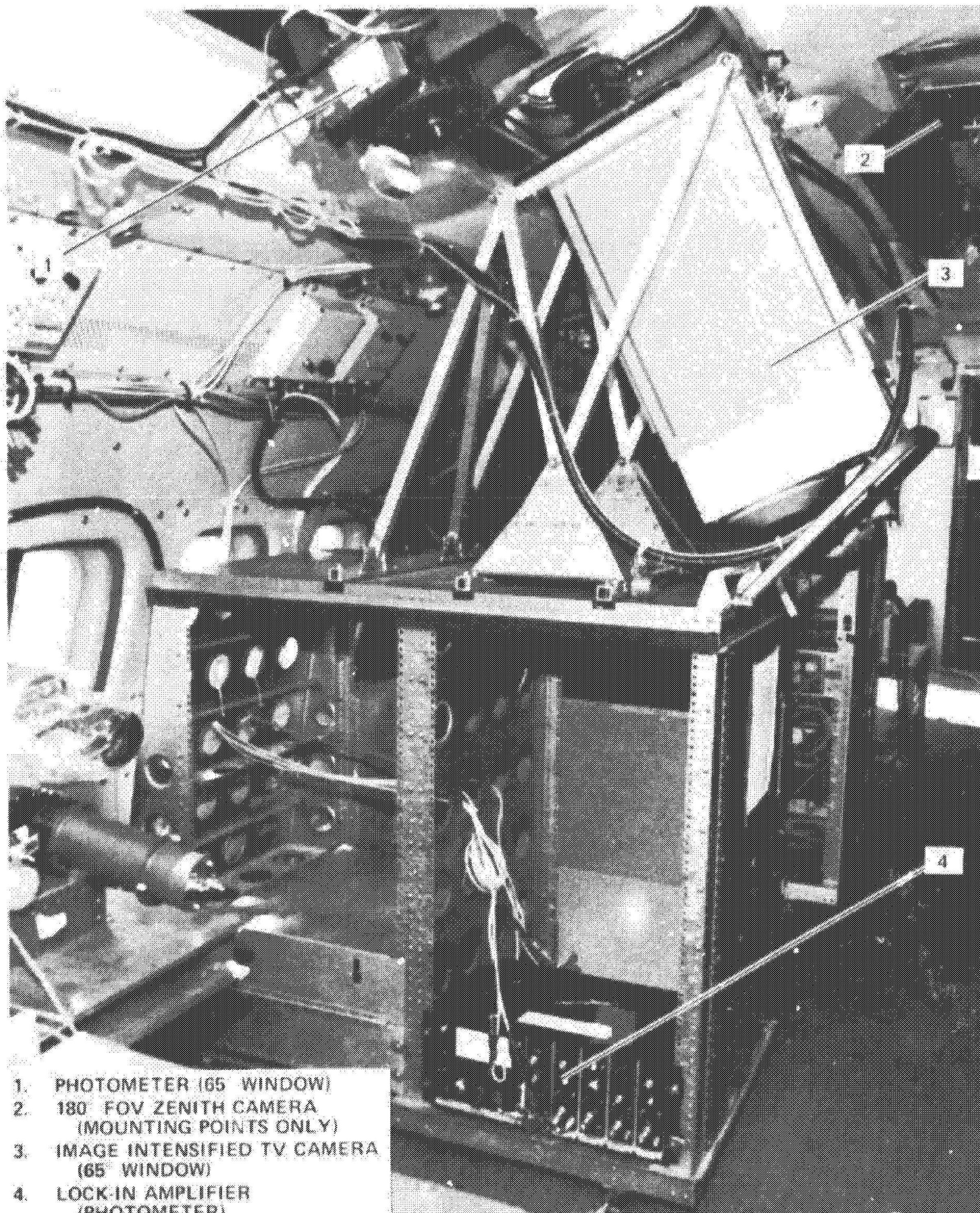
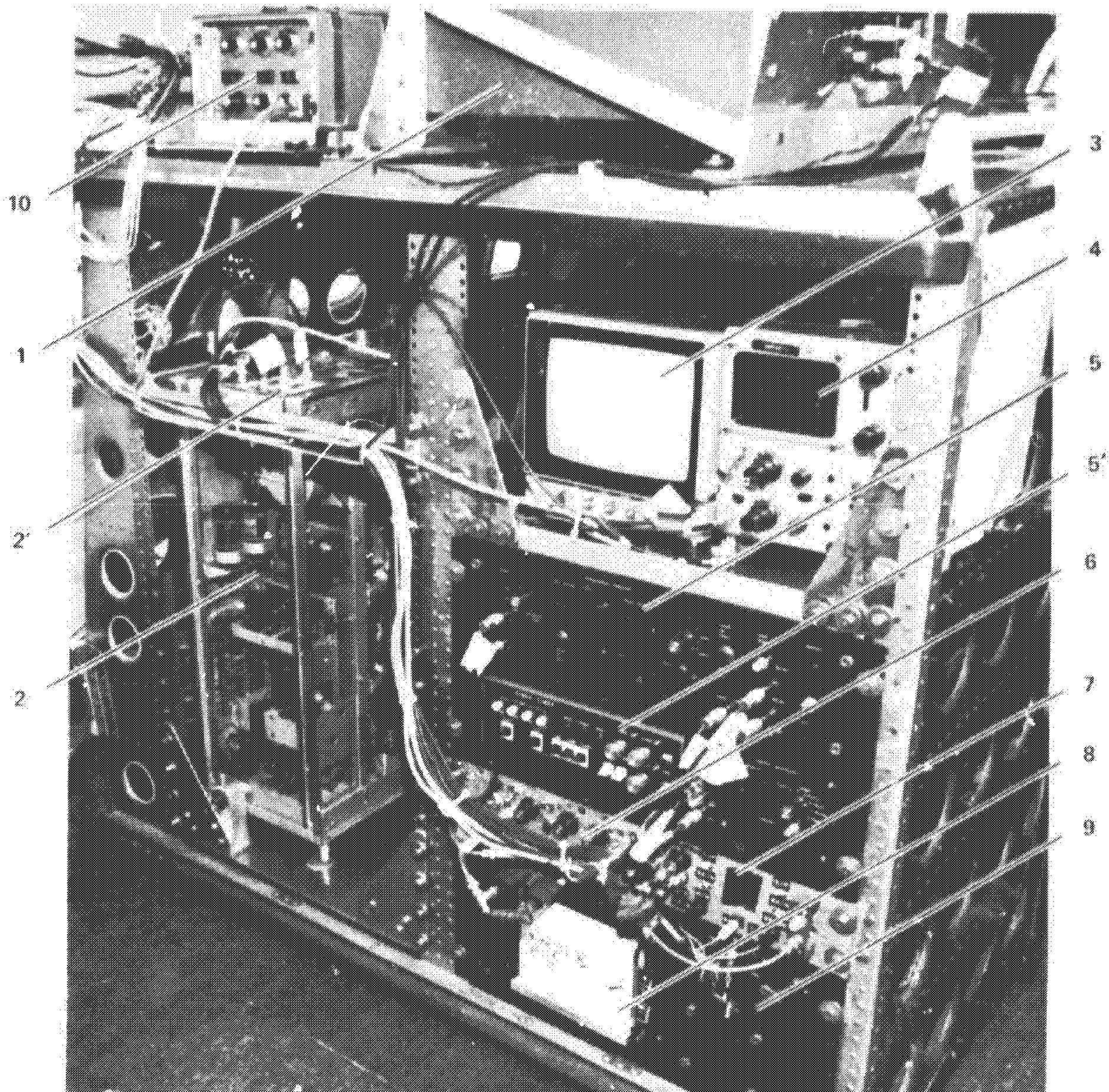


Figure B-7.- Southampton equipment configuration; rack C, photometer and zenith camera.



1. VIDEO TAPE RECORDER
2. IMAGE-INTENSIFIED TV CONTROL ELECTRONICS (2' CONTROL KNOBS)
3. TV MONITOR
4. OSCILLOSCOPE (VIDEO OR PHOTOMETER)
5. VIDEO INTEGRATOR CONTROL
5'. VIDEO TIME CONTROLS
6. 180 FOV ZENITH CAMERA CONTROL } SAME PANEL
7. PHOTOMETER CONTROL } SAME PANEL
8. STRIP-CHART RECORDER (SINGLE CHANNEL)
9. GENERAL POWER CONTROL
10. TV CONTROLS (BROUGHT OUT FROM 2) AND VOLTAGE MONITOR JACKS

Figure B-8.- Southampton equipment configuration, rack D.

top of the rack. However, operation still required some adjustment of controls on panel 2'. Another awkwardly placed component was the stripchart recorder (8), which recorded photometer output. The position of this component almost at floor level made it difficult for the EO to note the settings of photometer parameters on the chart recorder, a requirement set down by the PI. Components 2, 3, and 4 were mounted on shelves in the rack instead of being bolted to the rack flanges, the usual method of mounting components. There were no backup components in the Southampton racks.

Additional information on the components of this experiment is given in table B-7.

Experiment development and preparation- Table B-8 summarizes the development history of the experiment. Table B-9 details modifications of the experiment made especially for this mission. Experiment testing in preparation for this mission is listed in Tables B-10 and B-11. These tables were prepared by the ESA EOs in April 1975 and cover work at the University of Southampton up to shipment of the equipment to Ames via ESTEC.

Staffing and Support Requirements- Most of the work on the TV experiment was done by a single individual; he was a Ph.D. candidate working under the PI, and, although a competent experimenter, the additional activities introduced by preparation for the ASSESS mission placed considerable burden on him. He had useful technical support by another student, who specialized in the subsidiary experiments (infrared camera and infrared photometer). The PI's role was primarily administrative, but also included formulation of operational goals and evaluation of the progress made toward them.

Overall support requirements were relatively light because only modifications introduced for the ASSESS mission required unusual activity. The major components of the experiment had been in-house and in frequent use for about two years. However, early development of the major part of the experiment without flight in mind may have led to some inconvenience in control panel location in the flight environment.

Additional support was obtained from the University shop which provided a mechanical technician for a year's time. Also, the EO assigned to this experiment acted as a de facto member of the development team for about 40 days during his training period. He provided the development team with valuable assistance in the design, construction, and testing of specialized electronic circuits.

TABLE B-7.- SOUTHAMPTON COMPONENT INFORMATION

Component	Function	Construct.	Dimensions, cm			Power			Weight, kg	Cost, £	Comments
			Height	Width	Depth	V	A	W			
Video tape recorder	Records video output from camera, can record up to 1 in 49 pictures	Off-the-shelf	30	75	50	240	1	200	25	810	Purchase price (50 Hz only)
50-Hz reference unit and integration counter	Provides 50-Hz reference for scan oscillator; dials set on time for the camera[a]	Investigator built	27	49	33	240	0.04	10	10	50	Component cost only (50/60 Hz)
Time-code generator	Displays time with the data	Off-the-shelf	8	25	30	240	.62	15	4	300	Purchase price (50/60 Hz)
Oscilloscope	Monitors the composite video signal	Off-the-shelf	22	21	42	240 110	.5		12	200	Development cost (50/60 Hz)
Camera support frame	Structural framework required to fix camera to aircraft hard points	Investigator built	--	--	--	---	---		---	100	Component cost (est.)

[a]Provides a reference TV picture.

TABLE B-7.- Concluded

Component	Function	Construct.	Dimensions, cm			Power			Weight, kg	Cost, £	Comments
			Height	Width	Depth	V	A	W			
Camera head	Contains camera tube, scan coils, and a video signal pre-amplifier	Off-the-shelf	40	25	100				55	2,000 2,250	Previous development cost new tube
Camera control unit	Provides power to camera head, generates the scanning voltages and processes the returning video signal	Off-the-shelf	70	55	25	240 110	2.5 5	500 500	60	2,000	Previous development cost (50/60 Hz)
Steering unit	Contains controls once at the rear of camera head	Investigator built	15	21	14	---	---	---	1	10	Component cost only
TV monitor	Displays video	Off-the-shelf				240	0.1	24	5	150	Purchase price (50/60 Hz)
Disc storage unit	Stores last video pictures	Off-the-shelf							---	900	Purchase price
						Totals			>172	8770	

TABLE B-8.- SOUTHAMPTON EXPERIMENT DEVELOPMENT HISTORY

Component	Initial development date	Earlier modifi-cations	Previous field trips	Modifications for this mission	Time involved, days
Camera head and tube	Aug. 1973	None	Norway: Nov. 1973 Uist: Sept. 1974	Selection and calibration of new IR TV tube; internal controls moved to rack unit	2 5
Camera control unit	Aug. 1973	None	Norway: Nov. 1973	Provision made for inte-gration of TV picture over several frames; timing reference changed to crystal	4 1
Video tape recorder	Sept. 1974	None	None	Facility included for slow running of tapes; tapping of internal timing pulse	2
TV monitor	Aug. 1973	None	None	Smaller monitor bought for aircraft	--
Disc storage unit	Jan. 1975	None	None	Provides continuous viewing of intermittent data	--
50-Hz reference unit and inte-gration counter	Jan. 1975	None	None	Provides 50-Hz standard; controls camera in inte-gration time	27
Time-code generator	Jan. 1975	None	None	Displays time with date	--
Camera support frame and equipment mounting	Feb. 1975	None	None	Structural framework required to fix camera to equipment aircraft hard points	Design, 40; Construc-tion, 28

TABLE B-9.- SOUTHAMPTION EXPERIMENT MODIFICATIONS FOR THE JOINT MISSION

Camera head and tube
A new tube was obtained for the camera with a photocathode that gave the largest sensitivity in the required wavelengths.
The camera support collar was redesigned and strengthened.
Camera control unit
Previously the internal timing oscillator could be locked to the 50-Hz power-line frequency. The circuit was modified to lock to an external 50-Hz reference signal. A relay was incorporated in the "Beam" control circuit, enabling the scanning electron beam to be turned on or off by a pulse from the video tape recorder.
Video tape recorder
The standard VTR was replaced with one having the facility for slow running and the capacity to record data for a whole flight on a single magnetic tape. An internally generated timing pulse was tapped to drive the relay in the camera control unit.
Time-code generator
Adapted to fit a 19-inch rack.
TV monitor
A disc-memory unit was included with the monitor to permit storage and viewing of the infrequent (integrated) pictures by the EO without interrupting the data collection. A smaller monitor was bought for the aircraft.
50-Hz reference unit and integration counter
A 50-Hz reference unit was built to accommodate the European 625-line TV standard.
The integration unit was built to control the integration time in the camera.

TABLE B-10.- SOUTHAMPTON HOME-BASE TESTING

Component	Date of test	Type of test	Time for test	Test equipment	Problems or highlights
Camera head tube Control unit monitor	Periodic use prior to dispatch	System operational	1 day	Voltmeter Oscilloscope Test chart	To check functioning of new tube
Video tape recorder	Periodic use prior to dispatch	Operational	1 hour	Camera unit TV monitor	Need to clean tape path
50-Hz reference unit, integration counter	Jan. 20	Operational	3 days	Oscilloscope Tape recorder	None
Time-code generator	Jan. 10	Operational	1 hour	TV system	None

TABLE B-11.- SOUTHAMPTON TEST PROCEDURES, PREPARATION PERIOD AT AMES

50-Hz reference

Test 50-Hz sine-wave output on socket S50 R using oscilloscope.
Expect 9 V (peak to peak).

Camera/monitor

Set up the camera with control unit, TV monitor, and the oscilloscope monitoring the video signal. (Note the cable end at the input to the scope must be terminated in 50 ohms.)
Adjust mains, tapping panel to give a deflection in the green portion of the meter scale on the CCU.
Check alignment of camera by the picture quality.
Check the composite video signal on the oscilloscope:

Video	0.7 V max.
Blanking	0.1 V
Sync	0.2 V

Check picture stabilization when locked to 50-Hz reference.
No vibration test.

Video tape recorder

Perform test recording and replay both at normal and +7 speeds.
No vibration test.

Integration counter

Disconnect gate command cable SJ from scope socket SU and reconnect to socket SJ on CCU. Stop down lens until a low-intensity picture is seen (with both gain controls at 0.5 max). Run VTR at +7 speed and change mode control on integration unit to automatic.
Check that by adjusting "Beam Coarse" a good picture can be flashed on the screen. Dial up arbitrary numbers on the thumb switches on the unit. A picture should flash on the monitor as the timer readout gives zero.

University of New Mexico

This experiment, titled Photography and Photometry of OH Airglow Clouds, was sponsored by the Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico. The scientific objective was to study infrared OH airglow clouds near the horizon. The use of an airborne platform permitted calculation of cloud heights, and it was hoped that observations at various latitudes would confirm previous observations of variation in structure with latitude. Improved equipment permitted a finer examination of short-term variations in cloud structure than the investigators had been able to perform previously.

Basic instrumentation- The experiment equipment comprised two cameras and a photometer. A 35-mm camera and a 16-mm movie camera were both equipped with image-intensifier tubes to permit exposure times of the order of seconds, using wide bandpass filters covering 700-900 nm (figs. B-9 and B-10). The photometer (fig. B-11), with a red-sensitive photomultiplier as its detector, recorded airglow intensities through seven filters: four narrowband filters

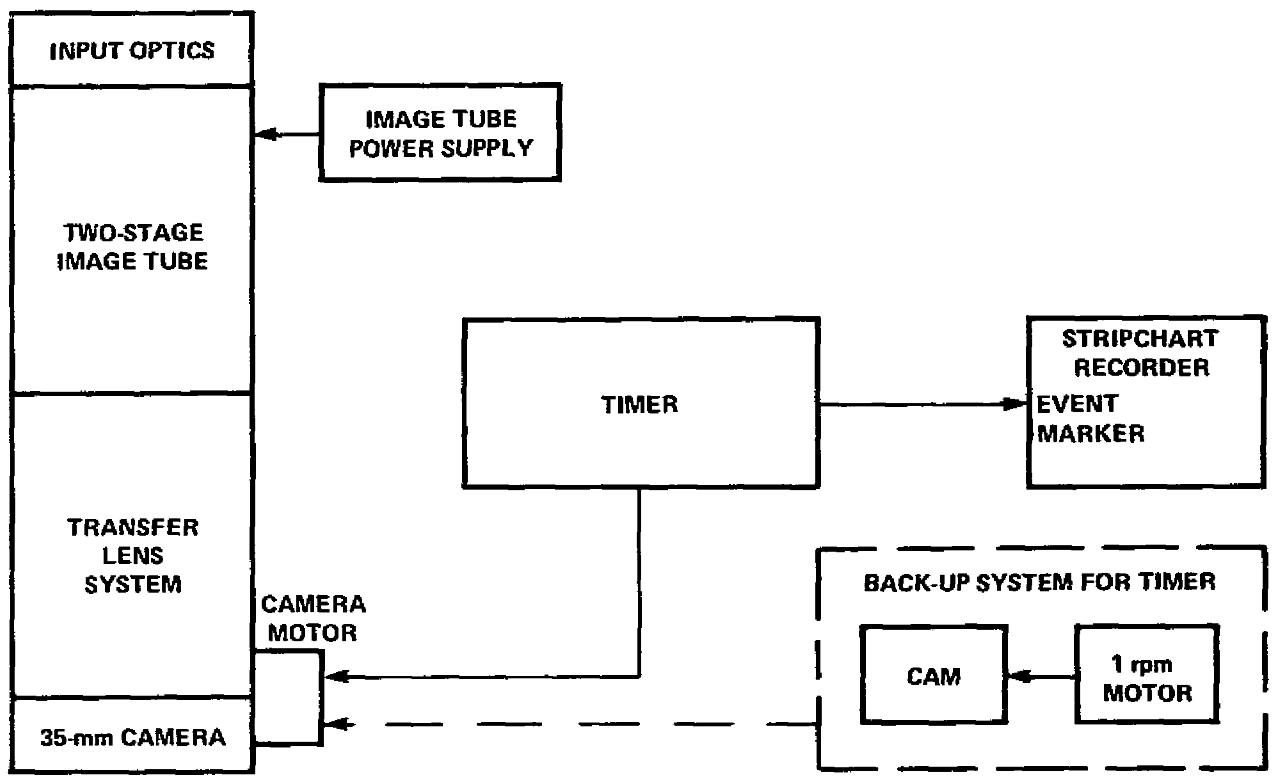


Figure B-9.- Block diagram of the New Mexico 35-mm image tube camera.

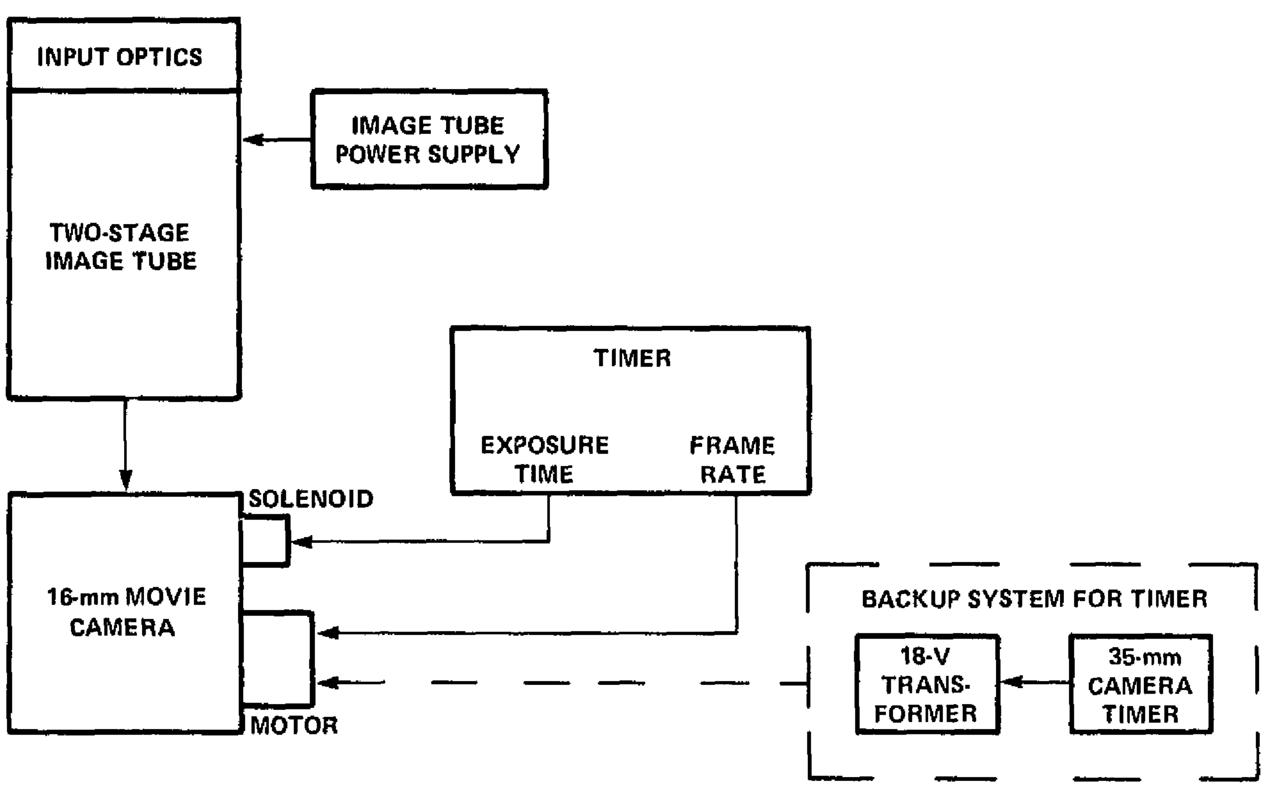


Figure B-10.- Block diagram of the New Mexico 16-mm image tube movie camera.

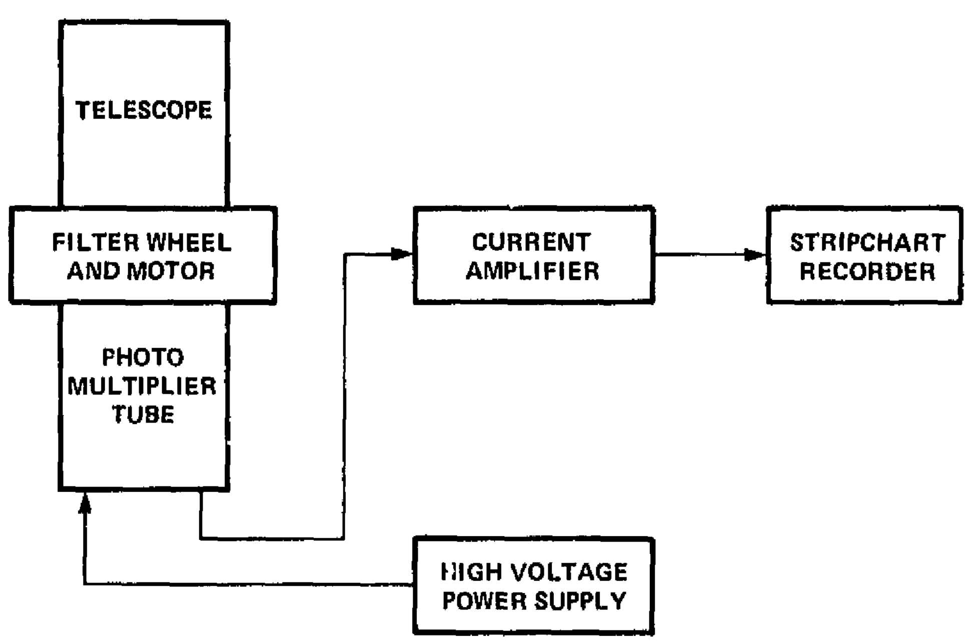


Figure B-11.- Block diagram of the New Mexico infrared photometer.

centered on individual airglow bands (690, 730, 790, and 840 nm); two narrowband filters centered between airglow bands to record background (710 and 820 nm); and one wideband filter identical to those used on the cameras for absolute calibration. The 16-mm movie camera made time-lapse exposures.

Equipment configuration- Figure B-12 shows the New Mexico equipment (less the 35-mm camera) as installed in the aircraft. The image intensifiers (1 and 4) and the photometer (2,3) were mounted on either end of a flat support beam. Between the two (not specifically noted in the figure) were mounted as individual units all camera timing devices and the power supplies for the image intensifiers. The usual approach to mounting small components is to group them on panels and to mount these in the equipment racks in the regular way. However, in the New Mexico installation this would have resulted in these controls being much nearer the floor and far less convenient to the EO.

This experiment included four backup components: two were used; a 1-rpm motor for firing the 35-mm camera (throughout the mission), and the backup strip-chart recorder (once as a New Mexico backup, and once as a backup to the QMC strip-chart).

Table B-12 provides additional information on the components of the New Mexico experiment.

Experiment development and preparation- Table B-13 summarizes the development history of the New Mexico experiment. Table B-14 details the modifications made by the coinvestigators specifically for this mission up to the time of delivery of the equipment to Ames. (A subsequent equipment substitution is discussed in the performance section.) The chronology of experiment preparation is presented in table B-15, and tests performed at the investigators home laboratory are listed in table B-16.

Staffing and support requirements- Table B-17 shows investigator and support time spent on preparation of the New Mexico experiment. During the period August 15 through December 23, 1974, both PI and coinvestigator worked full time designing, building, and modifying equipment, and obtaining observational data. It is estimated that at least 1/4 of these hours were spent in direct preparations for the ASSESS mission. During the 4-month period from mid-January through mid-May 1975, the PI devoted 3/4 time to the ASSESS experiment. The coinvestigator devoted 1/2 time during the 3-month period from mid-February to mid-May to the ASSESS experiment. Support requirements were minimal.

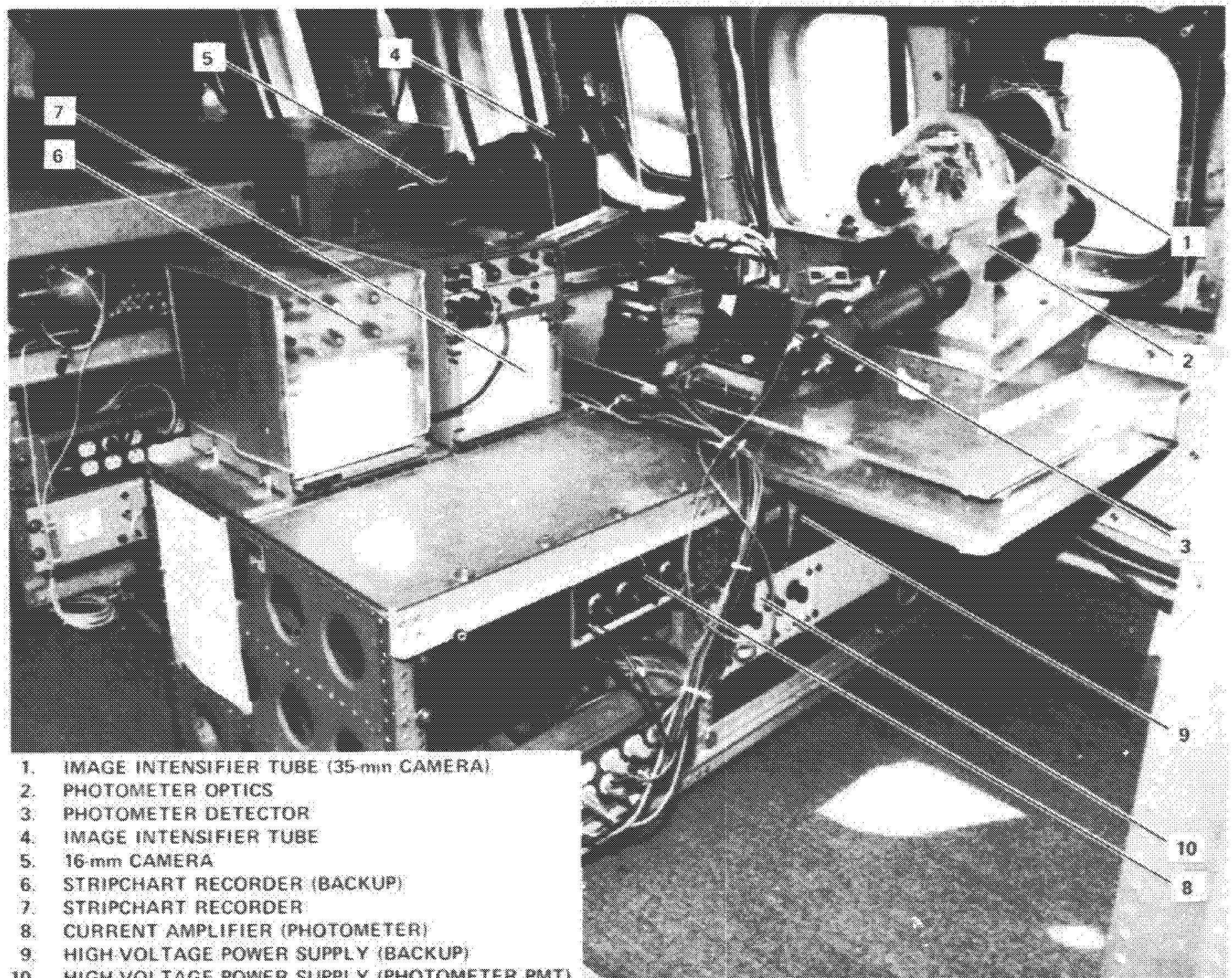


Figure B-12.- New Mexico equipment configuration.

TABLE B-12.- NEW MEXICO COMPONENT INFORMATION

Component function	Construction	Dimensions, cm			Power			Weight, kg	Cost, $	Comments
		Height	Width	Depth	V	A	W			
Stripchart recorder	Off the shelf	27.9	22.2	26.7	120		50	13.2	2200	
Backup stripchart recorder	Off the shelf	27.9	22.2	26.7	120		50	13.2	2200	
Current amplifier and panel	Off the shelf	7.6	48.3	30.5	120		5	3.2	895	Panel needed for mounting in standard rack
High-voltage power supply and panel	Off the shelf	13.3	48.3	35.6	120		90	7.5	350	Panel for mounting in rack
Backup high-voltage power supply	Off the shelf	13.3	48.3	27.9	120		90	6.8	0	Government surplus
Multioutlet AC panel	Off the shelf	8.9	10.8	34.3	120		--	1.4	8	
Stabilizing transformer	Off the shelf	12.7	8.3	20.3	120		--	6.4	30	
Isolating transformer	Off the shelf	14.0	11.4	15.2	120		--	13.6	69	
Image tube power supply	Modified	7.6	12.7	10.2	120		5	2.3	90	$30 list + $60 modification (6 hr at $10/hr)
Backup image tube power supply	Modified	7.6	12.7	10.2	120		5	2.3	90	See above
Photomultiplier tube and housing	Off the shelf	38.1	25.4	71.1	120			14.1	950 160	Tube Housing (16 hrs at $10/hr)
Telescope and field lens for PM tube	Investigator-built									
Filter wheel	Investigator-built								140	Design and materials
Seven filters	Off the shelf								119	$17 each
Transfer lens system for 35-mm camera	Investigator-built								40	System design 4 hr at $10/hr

TABLE B-12.- Concluded

Component function	Construction	Dimensions, cm			Power			Weight, kg	Cost, $	Comments
		Height	Width	Depth	V	A	W			
35-mm camera with bulk film cartridges, motor, battery pack, batteries, etc.	Off the shelf	38.1	25.4	71.1	120			14.1	1460	
Image tube for 35-mm camera	Custom								3400	Including housing
Mounting plate for PM tube and 35-mm camera	Investigator-built								50 150	Materials Design (15 hrs at $10/hr)
16-mm movie camera	Off the shelf	28.0	20.3	30.5	6.75		--	9.1	395	Second hand
Image tube for 16-mm camera	Custom								2450	Including housing
Motor for 16-mm camera	Off the shelf								120	
Mounting plate for camera and image tube	Investigator-built								150	15 hr at $10/hr (construction)
Backup 16-mm camera	Off the shelf							---	310	Second hand
Backup 16-mm camera motor	Off the shelf				12		--	---	142	
16-mm camera timer	Off the shelf	17.8	25.4	17.8	120		10	2.7	395	
35-mm camera timer	Custom	10.2	20.3	12.7	120		10	2.3	195	
Small lamp	Off the shelf	30	7	10	120		26	1	15	
3-stage image tube	Off the shelf	15.2	12.7	38.1	6.75		--	4.5	2050	For viewing from opposite side of plane
Voltmeter	Off the shelf	8	17	21	120		--	2.3	295	
Spare parts, instruction manuals, film, chart paper, tool box, etc.	Miscellaneous	~0.2 m^3						~20	500	Some are expendable
					Totals			125.9	19,418	

TABLE B-13.- NEW MEXICO EXPERIMENT DEVELOPMENT HISTORY

Experiment/component	Initial development date	Earlier modifications	Previous flights	Modifications for this mission	Time involved, hr
35-mm Photography					
35-mm camera with IR filter	Sept. 1972	None	None	Canon camera replaced by Topcon camera to allow bulk film capacity; includes electric motor, battery pack, 250-frame back	10
2-stage image tube, with housing and entrance lens	Oct. 1974	None	None		Selection and purchase, 12; housing fabrication, 24
Transfer lens system between image tube and camera	Jan. 1975	None	None		Design, 4; fabrication, 8
35-mm camera timer	Feb. 1975	None	None	Solenoid replaced by relays; new connectors installed; camera timer interface	4
Backup motor system consisting of 1-rpm motor and cam for 1-minute frame rate	April 1975	None	None		8
IR Photometry Photomultiplier tube 2-1/2 in. telescope Current amplifier High-voltage power supply Stripchart recorder	Spring 1973	Changed filters for airglow and eclipse observations Changed lens from quartz to achromatic glass	None	Jan. 1975: 2-filter board replaced by an 8-filter wheel with Geneva drive	Design, 20; fabrication, 16

TABLE B-13.- Continued

Experiment/component	Initial development date	Earlier modifications	Previous flights	Modifications for this mission	Time involved, hr
IR Photometry (contd.)					
Mounting plate	Spring 1973		None	Jan. 1975: redesigned to hold phototube and 35-mm camera	Design, 8; fabrication, 16
				Feb. 1975: redesigned to increase separation between camera and phototube; additional support panel for camera added	2
				March 1975: rebuilt in 3/8 in. aluminum at request of Ames engineers	16
16-mm Photography					
16-mm camera	Oct. 1974	Closeup lens for movie camera added	None	Jan. 1975: new closeup lenses added for larger image size	5
Image tube with housing and entrance lens				Nov. 1974: reject 3-stage image tube (poor image quality); replace with 2-stage tube	
				Nov. 1974: image tube housing	Design, 8; fabrication, 24
Timer				Feb. 1975: electric motor drive replaced hand-wound spring film advancer	5
Mounting plate				Feb. 1975: new mounting plate	Design, 15; fabrication, 8
				March 1975: rebuild mounting plate in 3/8 in. aluminum at request of Ames engineers	8

TABLE B-13.- Concluded

Experiment/component	Initial development date	Earlier modifications	Previous flights	Modifications for this mission	Time involved, hr
16-mm Photography (contd.)				April 1975: backup for motor, 24-V transformer to operate from 35-mm camera timer	8
Image tube power supply	Oct. 1974	Battery packs used originally	None	Jan. 1975: 12.5-V power supplies purchased	1
				Feb. 1975: modified to deliver 6.75 V using Zener diodes; later rejected in favor of bleeder chain	16
				Totals	Design, 70 Fabrication, 176

TABLE B-14.- NEW MEXICO EXPERIMENT MODIFICATIONS FOR THE JOINT MISSION

IR Photometer

1. Replaced 2-filter board with 8-filter wheel for extended spectral coverage.
2. Installed Geneva drive motor on filter wheel for completely automatic cycling of filters.
3. Changed lens from quartz to achromatic glass.
4. Designed mounting plate to hold photometer and 35-mm camera system.
5. Rebuilt mounting plate from 3/8 in. aluminum at request of Ames engineers.
6. Replaced bolts on mounting plate with NAS hardware.
7. Installed extension panels on high-voltage power supply and current amplifier so they can be mounted in standard 19 in. rack.
8. Ordered event marker pens for each chart recorder.
9. Added a neutral density filter to wideband filter to lower total signal so that it will be within recorder range.
10. Labeled electronic components and cables for easy identification by EOs.
11. Added complete second set of cables for possible operation on opposite side of airplane.

16-mm Photography

1. Replaced 3-stage image tube with 2-stage tube for better image quality.
2. Replaced closeup lenses between camera and image tube.
3. Designed and built new mounting plate.
4. Rebuilt mounting plate in 3/8 in. aluminum at request of Ames engineers.
5. Replaced all bolts on mounting plate with NAS hardware.
6. Added electric motor so EO will not need to hand-crank the spring-driven film advancer.
7. Added transformer to operate motor from AC line.
8. Installed resistor in parallel with transformer primary to reduce noise spikes.
9. Added spring loading device on universal joint between motor and camera to prevent slipping.
10. Replaced cap screws for securing camera to mounting plate with large knurled knobs for ease in removing camera.
11. Interchanged instruments' positions to allow EO easier access for changing movie film.

35-mm Photography

1. Added 2-stage image tube to reduce exposure times to seconds to cut down on smearing due to plane motion.
2. Added new camera with bulk film capacity so EO will not have to change film so often.
3. Designed new transfer lens system to be compatible with new camera.
4. Added timer so that exposure time and frame rate will be controlled automatically.
5. Designed new image tube housing to accept Canon F/1.2 input lens.
6. Made camera-timer extension cord.
7. Modified 12.5-V power supply to provide 6.75 V for the image tube to replace battery pack.
8. Rewired image tube to be compatible with power supply.

TABLE B-14.- Concluded

9.	Installed new one-pin connectors in image tube power supply to replace previous two-pin connectors.
10.	Installed dark slides on all three image tubes.
11.	Filed detent notch on dark slide rod to prevent dark slide from inadvertently closing.
12.	Built backup timing system consisting of 1-rpm motor, cam, and microswitches.
13.	Increased separation between photometer and camera system to accommodate additional support panel for camera on mounting plate.

TABLE B-15.- NEW MEXICO HOME-BASE PREPARATION AND PERFORMANCE

Investigator's schedule	Investigator's actual work
Week of October 7	
1. 7 nights operational tests (observations)	3 nights bad weather, 4 nights observations
2. Receive new 2-stage image tube (to be used with movie camera)	Delivered Sept. 24
Week of October 14	
1. 7 nights operational tests (observations)	3 nights observations, 3 nights bad weather
2. Return new 2-stage image tube for repotting (it was poorly centered)	Received back Oct. 22
3. PI attends experimenters' meeting at Ames	On schedule
Week of October 21	
1. 3 nights operational tests (observations)	3 nights observations, 4 nights moon
Week of October 28	
1. Order Topcon camera and accessories	Completed Nov. 3
2. Prepare and submit revised budget for ASSESS mission	On schedule
Week of November 4	
1. 7 nights operational tests (observations)	2 nights observations, 5 nights bad weather
2. Filter-wheel design sent back to UNM machine shop	On schedule
3. Order backup image tube	Completed
Week of November 11	
1. 6 nights operational tests (observations)	3 nights observation, 3 nights bad weather
Week of November 18	
1. ESRO meeting in Paris	Attended by PI and coinvestigator
Week of November 25	
1. 1 night operational tests (observations)	1 night observation, moon in sky for other nights
2. Send sketches, bolt hole patterns, and request for N-S flight to Ames	Completed Dec. 6
Week of December 2	
1. 7 nights operational tests (observations)	4 nights observation, 3 nights bad weather

TABLE B-15.- Continued

Investigator's schedule	Investigator's actual work
Week of December 9	
1. 7 nights operational tests (observations)	4 nights observation, 3 nights bad weather
2. Design new mounting plates for cameras and photometer	On schedule
Week of December 16	
1. 7 nights operational tests (observations)	2 nights observation, 5 nights bad weather
2. Pack up equipment for shipment to New Mexico	Completed Dec. 22
December 23 - January 12	
No work scheduled	No work due
Week of January 13	
1. Unpack equipment from Hawaii	On schedule
2. Order spare 35-mm camera back	Not done — one already on hand will be used as a backup. It does not have bulk film capacity.
3. Filter wheel completed by machine shop	Completed Jan. 22
4. Delivery of spare image tube	Arrived March 25
Week of January 20	
1. Assembly of equipment in experiment rack	Not done — will be done at Ames
2. Receive and check out Topcon 35-mm camera system	On schedule
3. Order 12.5-V power supplies for image tubes	Completed Jan. 28
Week of January 27	
1. Design 35-mm camera-image tube interface and housing for transfer lens system	Completed Feb. 5
2. Order timer for 35-mm system	On schedule
Week of February 3	
1. Design backup motor drive system for 35-mm camera	Completed April 2
2. Modify 12.5-V power supplies to provide 6.75 V for image tubes	On schedule
3. Order closeup lens for movie camera	Received Feb. 18
Week of February 10	
1. Training of EO in New Mexico	Not done till week of March 10
2. Test possible transfer lens systems for 35-mm system	On schedule

TABLE B-15.- Continued

Investigator's schedule	Investigator's actual work
Week of February 17	
1. Test electric motor for movie camera	On schedule. Slipping universal joint remedied March 5
2. Receive timer for 35-mm camera system	Received March 4
3. Redesign mounting plate to provide more support for 35-mm camera	On schedule
4. Test assortment of closeup lenses for movie camera to obtain 4:1 image	Completed Feb. 27
Week of February 24	
1. Test two high-voltage power supplies for stability	Completed March 5
2. Test filter wheel for continuous operation	Completed March 12
Week of March 3	
1. Preparation of EO checklists for operating equipment during flight	Completed March 11
2. Send out stripchart recorders for servicing and calibration	On schedule
3. Test two image power supplies for stability	On schedule
4. Rebuild mounting plates in 3/8 in. aluminum	Completed March 20
Week of March 10	
1. Test operational reliability of bulk 35-mm film transport	On schedule
2. 3-4 nights operational tests (observations)	None performed; weather did not cooperate
3. Visit of 2 EOs	Whole week devoted to EO training
Week of March 17	
1. Flight Readiness Review by telephone	On schedule
2. Wire an extension cord for camera timer	On schedule
Week of March 24	
1. Test longevity of 35-mm camera battery pack	On schedule
2. Send requested information to Ames on sizes and positions of rack-mounted equipment	On schedule

TABLE B-15.- Continued

Investigator's schedule	Investigator's actual work
Week of March 31	
1. 2-3 nights operational tests (observations)	Successful runs in the field on 2 nights
2. Intensity calibration of IR photometer	Completed April 15
Week of April 7	
1. 2-3 nights operational tests (observations)	None, weather uncooperative
Week of April 14	
1. Test the "repaired" printer returned from factory	On schedule; not successful in adapting printer to our system. It will not be used.
2. Determine transmission curves of narrowband filters for IR photometer and wideband filters for cameras	On schedule
3. 2-3 nights operational tests (observations)	2 nights of successful runs in the field
Week of April 21	
1. Shipment of flight instruments to Ames	Shipment sent on April 27
2. Spare image tube returned to factory to remove Newton's rings	Received back on May 1
3. Begin required paperwork due on arrival at Ames	Completed May 15
Week of April 28	
1. Test compatibility of bulk film cartridges with camera magazine	On schedule. Nine are compatible; 3 have occasional failures.
2. Purchase 2 additional bulk 35-mm film cartridges	On schedule
3. 2-3 nights of operational tests (observations)	1 successful observing run
4. Send test films to Ames photo lab for sample processing	On schedule
5. Test backup motor drive system for 35-mm camera	On schedule
6. Prepare EO instruction sheets for changing film in both cameras	Completed May 2

TABLE B-15.- Concluded

Investigator's schedule	Investigator's actual work
Week of May 5	
1. PI drives to Moffett Field	On schedule
2. Purchase backup motor for movie camera	On schedule
3. Continuation of paperwork due on arrival at Ames	On schedule
Week of May 12	
1. Coinvestigator flies to Moffett Field	

TABLE B-16.- NEW MEXICO HOME-BASE TESTING

Component	Date	Type of test	Time tested	Test equipment used	Problem or highlights
Photomultiplier system, including amplifier, high-voltage supply and chart recorder	55 days during period Sept. 3 to Dec. 20, 1974	Operational	300 hr (in stretches of 2 to 9 hr)	None but system components	Very reliable performance of all components
Stripchart recorders	March 6, 1975	Calibration, range adjustment and servicing	4 hr	Performed by factory representative in his own lab	Ranges are now accurate; slipping belt on older model was replaced
High-voltage power supply	March 5, 1975	Stability without stabilizing transformer	4 hr	Digital voltmeter	<1-V variation in 750 V; entirely satisfactory
Backup high-voltage supply	March 5, 1975	Stability without stabilizing transformer	4 hr	Digital voltmeter	5 V in 750 V
Filter-wheel motor	March 12, 1975	Operational	5 hr	None (monitored with chart recorder)	No problems
Filters for photometer	April 16, 1975	Determination of filter transmission curves	3 hr	Cary-14 spectrophotometer belonging to UNM Chemistry Dept.	Filters are very close to manufacturers specs
Image tube power supplies	March 3, 1975	Stability of voltage after modification	3 hr	Digital voltmeter	5 mV in 6.75 V; acceptable

TABLE B-16.- Continued

Component	Date	Type of test	Time tested	Test equipment used	Problem or highlights
Printer (returned after factory repairs)	April 23, 1975	Operational test of factory revisions	12 hr	Oscilloscope, voltmeter	Unable to make print on command; will not fly with experiment
35-mm camera system including image tube, timer, and motor drive	April 3, 1975 April 4, 1975 April 17, 1975 April 18, 1975	Operational	12 hr	None	Exposure time controlled more accurately by internal camera mechanism than by external timer: exposures of 1 sec or less are desirable
35-mm camera transfer lens system	Feb. 11-14, 1975	Image quality and 1:1 image size	4 days	Various combinations of lenses and extension tubes	None has good extra-axial image quality; best performance is by a CRT 1:1 transfer lens (installed)
Battery pack for 35-mm camera motor	March 25, 1975	Operational		None	Battery pack will need to be charged after each night's use
Bulk magazine for 35-mm camera	March 12, 1975 April 28, 1975	Operational to check reliability of film transport	8 hr	Film and bulk film cartridges	About 1 failure in 20 tries; EO will have to watch out for this
Bulk film cartridges for 35-mm camera	April 29, 1975	Operational; cartridges and camera back compatible	4 hr	12 cartridges and film	9 OK; 3 fail on occasion. The good ones are marked with white dots to be used on aircraft flights. Other ones will be used only in emergency with special instructions to EOs

TABLE B-16.- Continued

Component	Date	Type of test	Time tested	Test equipment used	Problem or highlights
Movie camera system including image tube and timer	30 days during period Sept 3 to Dec. 20, 1974	Operational	75 hr (in stretches of 1 to 3 hr)	None	Very reliable, but spring for motoi must be wound every 2 hr
Electric motor for movie camera	Feb. 19-20, 1975	Operational	10 hr	None	Slipping universal joint resulting in frame jitter; resolved by spring-loading motor
Closeup lens system for movie camera	Nov. 19, 1974 Feb. 19, 1975	To achieve 4:1 image reduction	20 hr	Closeup lens and one short extension tube	Poor to fair
				Home-made extension tubes	Poor
				Two readymade close-up lenses	Best so far; this one will be used
Backup motor drive system (trans-former, 1 rpm motor, cam)	April 30, 1975	Operational	3 hr	Resistors, voltmeter	Erratic timing sig-nals due to tran-sients in trans-former; large resistor used in parallel with transformer primary to reduce power factor
Black cloth for curtains	May 6, 1975	Flammability	1 sec	Matches	It burns
Backup image tube	April 21, 1975	Operational	3 hr	Regular movie camera system	Newton's rings between cover plate and output optics; corrected at factory

TABLE B-16.- Continued

Component	Date	Type of test	Time tested	Test equipment used	Problem or highlights
IR filters for 35-mm and 16-mm cameras (and backup filters)	April 18, 1975	Determination of transmission curves	2 hr	Cary-14 spectrophotometer in UNM Chemistry Dept.	None
IR photometer system	April 15, 1975	Intensity calibration	3 hr	Laboratory black body at 1000 K and 6 apertures, 14 in. collimator	Black-body signals too high, photometer aperture stopped down and amplifier gain reduced
IR photometer system	April 17 1975	Intensity calibration	4 hr	Black body at 800 K, 900 K, and 1000 K, and 6 apertures, 14 in. collimator	Consistent calibration obtained
4X film (16-mm)	Oct. 12-13, Oct. 13-14, Dec. 5-6, Dec. 6-7, Dec. 12-13, Dec. 23-24, 1974	Operational to determine exposure and developing time	Exposure: 18 hr Developing: 12 hr	D-19, 9 min at 65° F	2-sec exposures gave good density
2475 film (35-mm)	April 3-4, 1975	Operational for exposure times and developing procedures	Exposure: 1 hr Developing: 1 hr	D-76, 5-1/2 min	1 sec, 1/2 sec, and 1/4 sec at F/1.2, and 1 sec at F/2 OK; all other F-stops underexposed
4X film (35-mm)	April 4-5, 1975	Operational for exposure times and developing procedures	Exposure: [illegible] hr Developing: 6 hr	D-19, 12 min D-19, 6 min	2 sec at F/1.8 looks good
2475 film (35-mm)	April 16-17, 1975	Operational to determine exposure and developing times	Exposure: 1 hr Developing: 1 hr	DK-50, 7 min, 70° F	1/2 sec at F/1.2 is best

TABLE B-16.- Concluded

Component	Date	Type of test	Time tested	Test equipment used	Problem or highlights
2475 film (16-mm)	April 16-17, 18-19, 1975	Operational to determine exposure and developing times	Exposure: 3 hr Developing: 2 hr	DK-50, 18 min, 68° F	0.7 sec underexposed; film not uniformly wetted with pre-hardening bath
2475 film (35-mm)	April 18, 1975	Operational to determine exposure time	3 hr	NASA photo lab processing with Versamat "A" chemicals and various speeds	Report from Photo Lab: desired density obtainable with exposures 1 sec or less
2475 film (16-mm)	May 3-4, 1975	Operational to determine exposure and developing times	Exposure: 2 hr Developing: 2 hr	DK-50, 18 min, 68° F (overdeveloped by 1/3)	1-sec exposure; rinse before prehardening bath — great improvement — density fine
		Total	565 hr		

TABLE B-17.- NEW MEXICO EXPERIMENT STAFFING

Staff and tasks	Support time, hr	Support preparation, %
Principal investigator and coinvestigator, 1/4 time for 18 weeks (August-December 1974)		
Principal investigator	180	
Coinvestigator	180	
Subtotal	360	
Principal investigator, 3/4 time for 18 weeks (mid-January to mid-May 1975)		
Design and/or modification	330	60
Tests	160	30
Paperwork	50	10
Subtotal	540	
Coinvestigator, 1/2 time for 12 weeks (mid-February to mid-May 1975)		
Design and/or modification	20	10
Tests	100	40
Paperwork	120	50
Subtotal	240	
Student and secretarial help, 1/3 time for 4 weeks	50	
TOTAL	1190*	

*Does not include time required to attend meetings.

Meudon Observatory/University of Groningen

This experiment, titled High-Resolution Mapping of Dark Clouds and HII Regions, was jointly sponsored by the Infrared Space Group, Observatory of Meudon, France, and the Space Science Group, Astronomy Department, University of Groningen, The Netherlands. The Meudon group provided the telescope and the Groningen group the detector. On a few flights, the Groningen detector was replaced by a detector from Ames, described as a separate experiment in the next section.

Both giant and compact HII regions are now known to be strong emitters of infrared radiation. The mechanism responsible for infrared emission is thought to be heating of dust particles by absorption of ultraviolet photons arising from a central source (a single hot star or cluster of early type stars). In most cases, the central object is surrounded by an ionized region. Very young objects have been observed in a few regions indicating that star formation might be understood through the study of the physical properties in these regions.

More recently, dark clouds have been suggested as ideal candidates for the study of star formation. In fact, dark clouds and HII regions would be inequally evolved objects of the same physical nature. As an example, the prominent dark clouds complex near Ophiuchus is thus comparable to the Orion Nebula. Both regions have been observed in visible, near infrared, and radio wavelengths, but the Ophiuchus region appears to be particularly well suited for an aircraft program for various reasons:

- Relatively small distance (<200 parsecs)- Thus a poor angular resolution corresponds to a reasonable linear resolution; that is, 1 arc min ≈ 0.06 parsecs

- Cold object (30 K instead of 70 K for Orion)- This source cannot be observed at 20 μm or 30 μm from ground-based observatories. The maximum brightness should occur around 100 μm

- Less evolved object in which star formation has been very efficient

For a detailed understanding of the processes in such sources, it is required that the spatial structure of the sources be known at different wavelengths. Such knowledge would allow the determination of the temperature gradient in the dust and — together with radio observations — establish the absorption characteristics of the particles.

Basic instrumentation- The instrumentation consisted of a 30-cm open-port telescope and a cryogenically cooled bolometer as a detector for the infrared signal. The telescope was gyrostabilized to overcome small motions of the aircraft. In addition, a television-controlled spot follower provided automatic tracking after location of a desired target star. The telescope could also be programed to scan an area with a raster of selected size.

The Groningen detector was a four-channel infrared photometer operating in the following wavebands: 17-20 μm, 30-38 μm, 70-95 μm, and 114-196 μm. The signal was amplified and synchronously detected in a conventional manner and recorded in digital form on magnetic tape.

Figure B-13 is a block diagram of the entire Meudon/Groningen system. (Translation of the French captions is given on the page following figure B-13.)

Equipment configuration- Figure B-14 shows the Meudon telescope just after its installation aboard the aircraft and during a period of operational check-out with simulated signals (from the teletype console in the background). After the completion of the telescope check the associated electronics racks were installed as shown in the floor-plan given earlier (fig. B-1).

The details of rack loading for this complex experiment are given in figures B-15 through B-19 which show racks F, G, H, I, and J, respectively. Racks F, H, and J contain only Meudon components related to telescope control. Groningen components shared the lowboy rack (G) with Meudon and filled the outboard bay of rack I. Most components were mounted in the racks using the

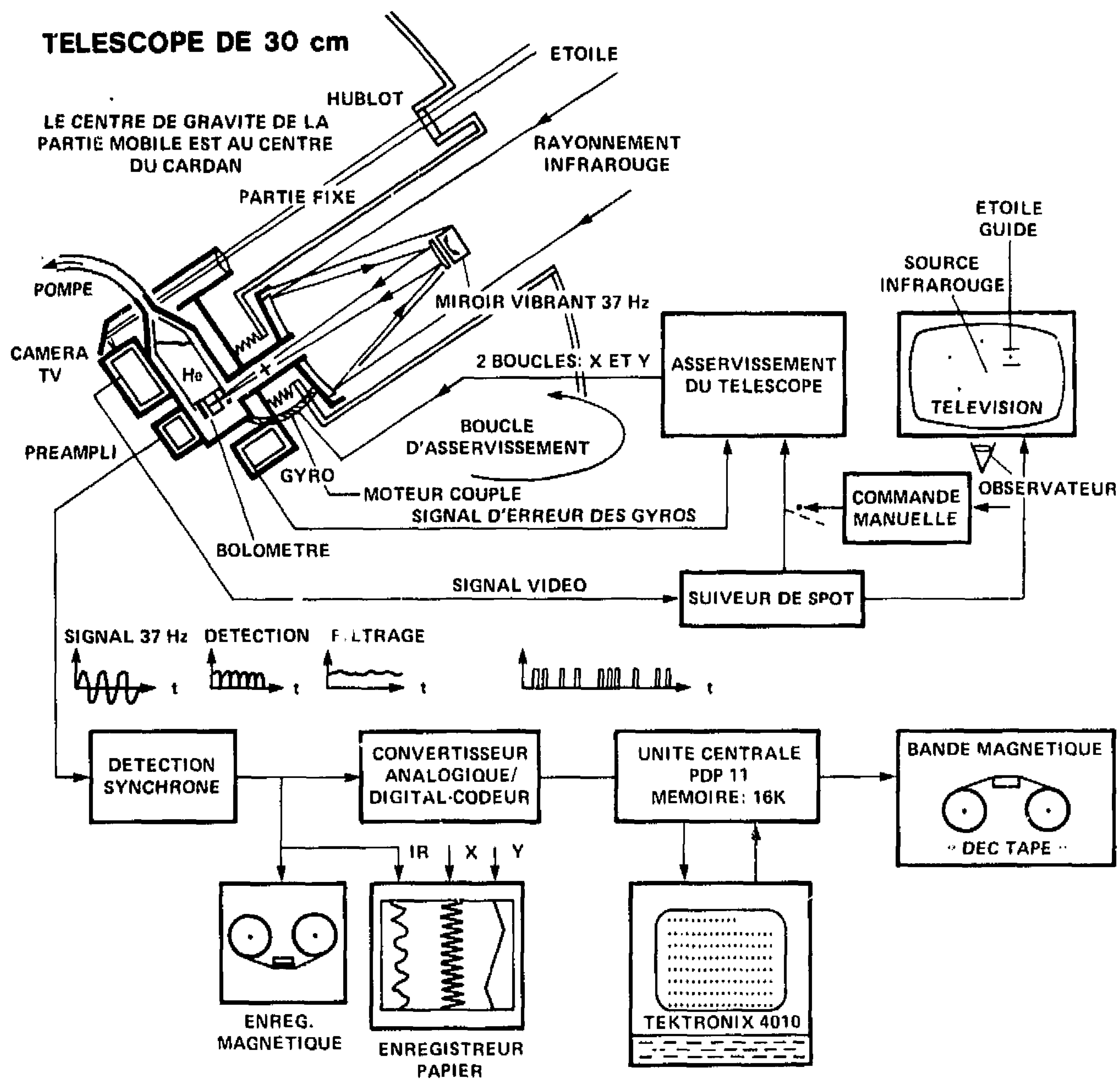


Figure B-13.- Block diagram - Meudon/Groningen experiment.

TRANSLATION OF FRENCH CAPTIONS

étoile - star

hublot - port

partie fixe - fixed portion

rayonnement infrarouge - infrared ray

miroir vibrant - oscillating mirror

asservissment du telescope - telescope servo electronics

suiveur de spot - spot follower

étoile guide - guide star

detection synchrone - synchronous detector

convertisseur analogique/digital - analog to digital converter

enrégistreur magnetique - magnetic tape recorder

enrégistreur papier - paper chart recorder

filtrage - signal after filtering

pompe - vacuum pump

boucle d'asservissement - servo loop

signal d'erreur des gyros - gyro error signal

le centre de gravité de la partie mobile est au centre du cardan - the center of gravity of the moving part (of the telescope) is at the center of the gimbals

moteur couple - torque motor

bande magnetique - magnetic tape

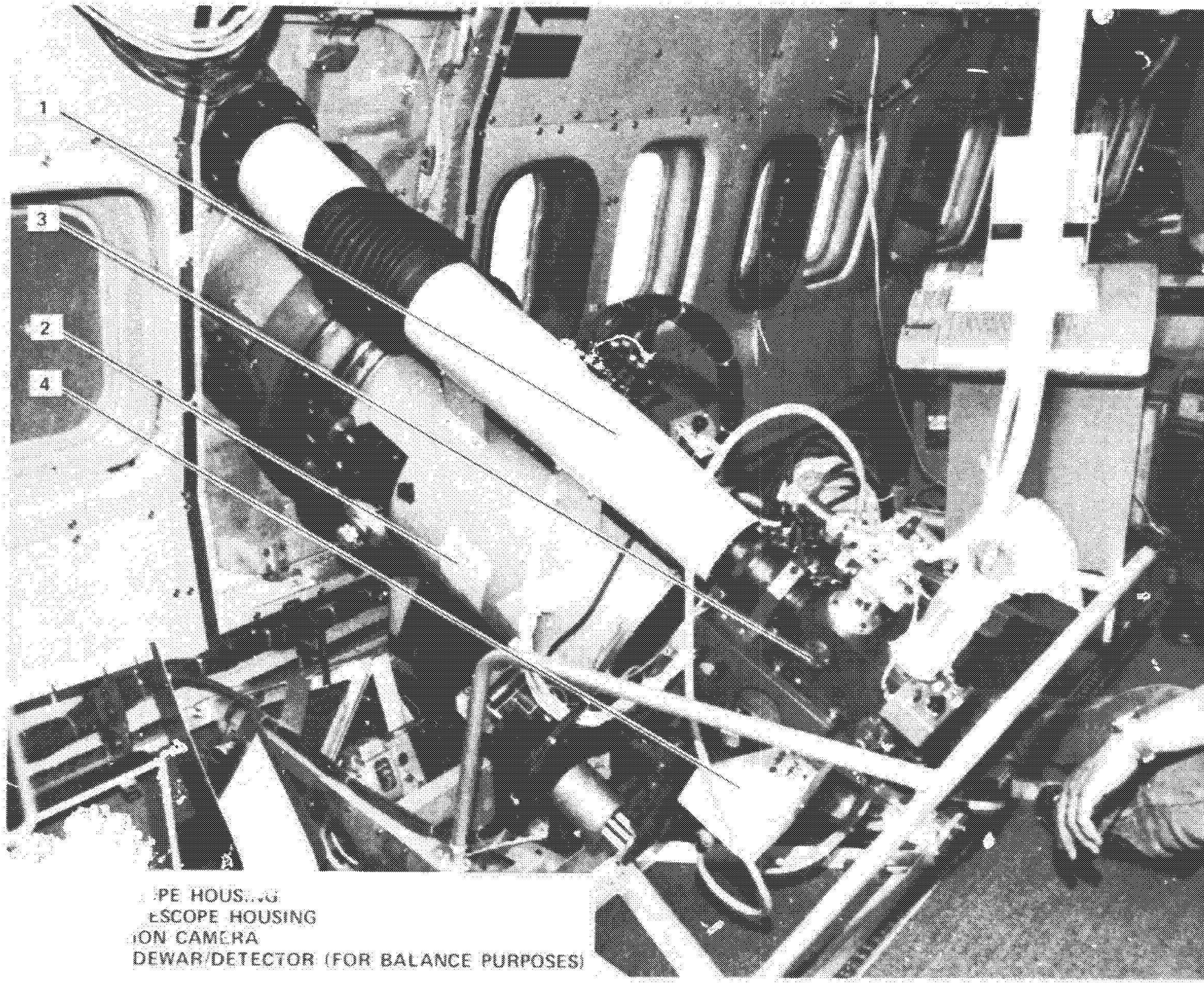


Figure B-14.- Meudon telescope.

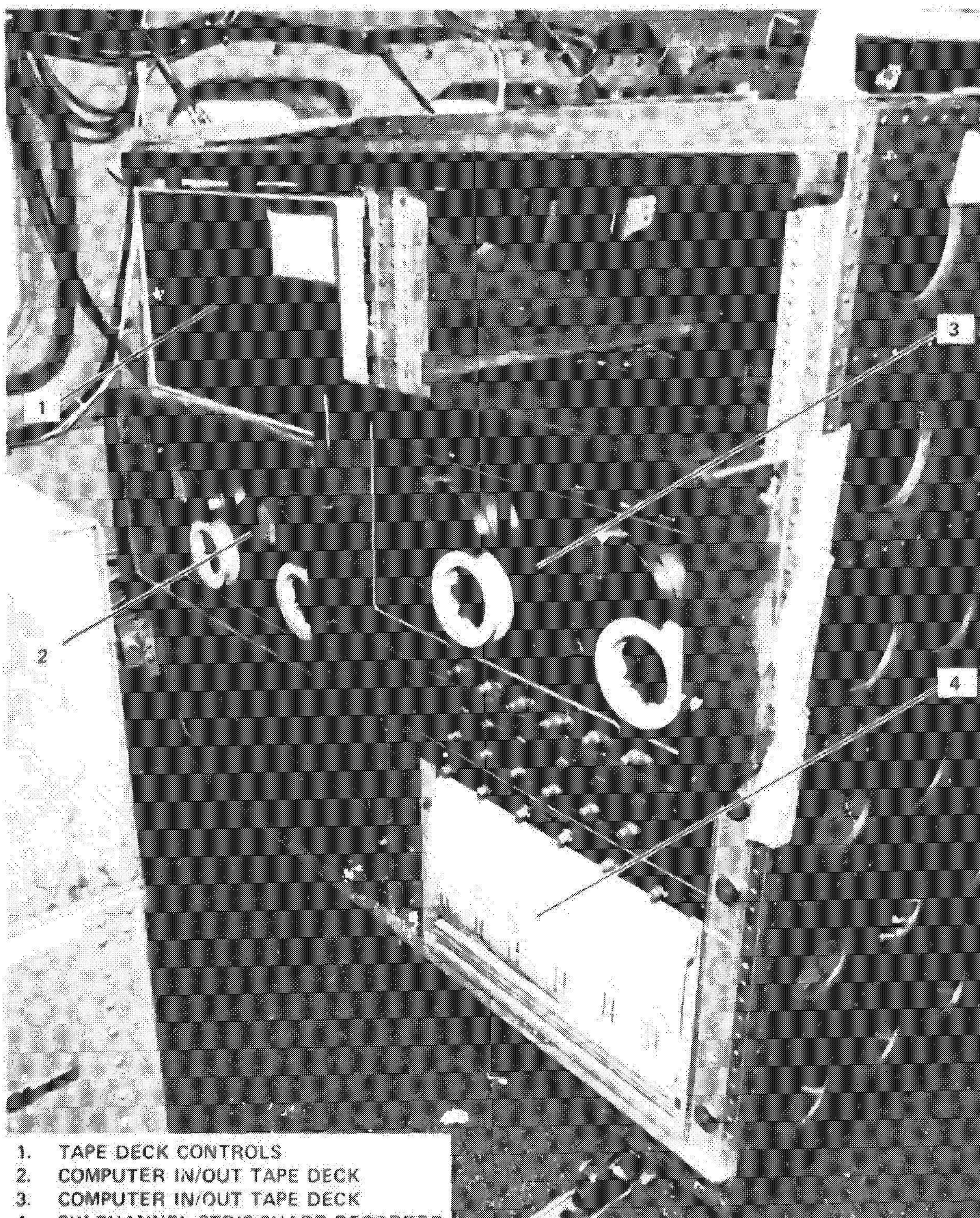
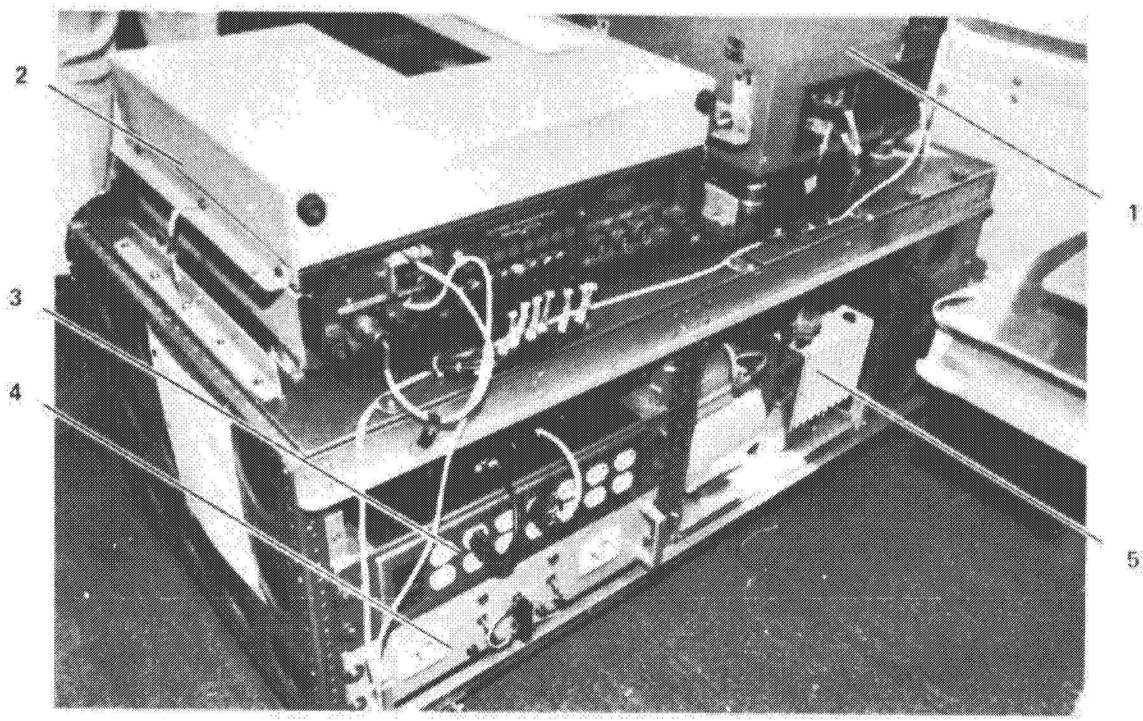
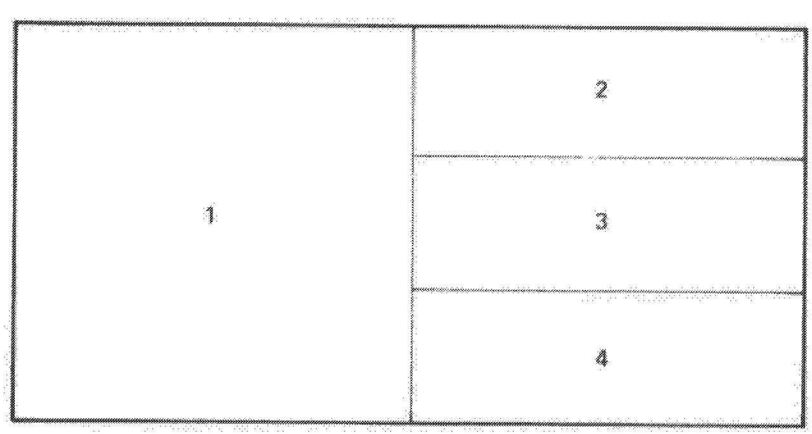


Figure B-15.- Meudon equipment configuration, right front rack (F).



A) FORWARD SIDE

1. VIDEO TAPE RECORDER (MEUDON)
2. DIGITAL TAPE RECORDER (MEUDON/GRONINGEN)
3. 60-Hz POWER DISTRIBUTION
4. 220 V AC POWER SUPPLY (GRONINGEN)
5. VACUUM PUMP (GRONINGEN)



B) AFT SIDE

1. PRESSURE CONTROL (GRONINGEN)
2. AMP-ISOLATORS (8-GRONINGEN)
3. AC AMPLIFIER (GRONINGEN)
4. PHASE SENSITIVE AMPLIFIER (GRONINGEN)

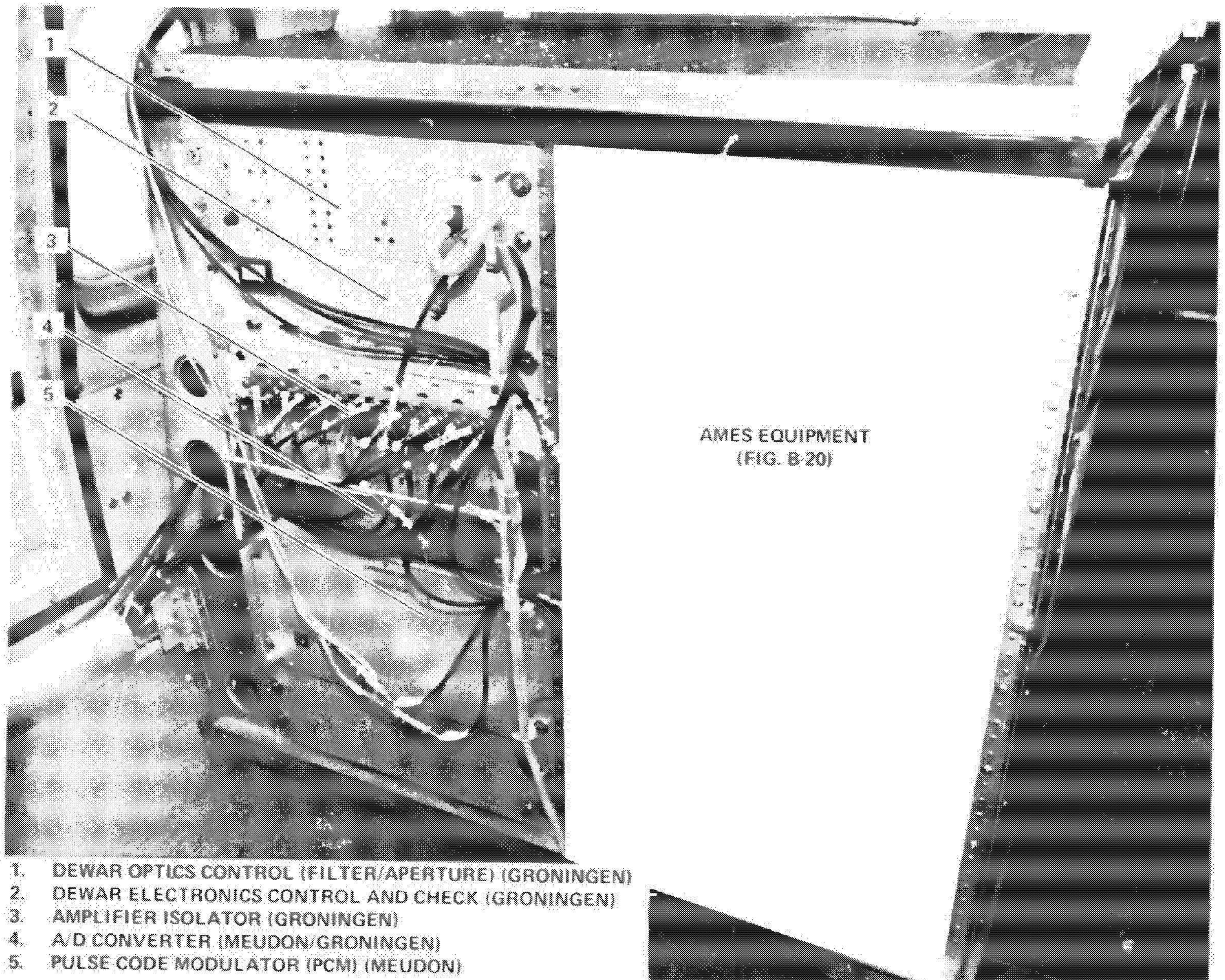
Figure B-16.- Meudon equipment configuration, lowboy rack G.

1. COMPUTER TERMINAL
2. OFF-SET CONTROL
3. TAPE DECK CONTROL (INOPERATIVE) AND TV CAMERA CONTROL
4. I/O TO COMPUTER TERMINAL
5. STAR-FIELD MONITOR
6. SERVO LOOP CONTROL
7. COMPUTER
8. PULSE-CODE MODULATION (PCM) DEMODULATOR (TO COMPUTER)
9. COMPUTER INTERFACE
10. CCTV (AIRCRAFT PARAMETERS)

28-V DC POWER SUPPLY (FORWARD CARGO HOLD)

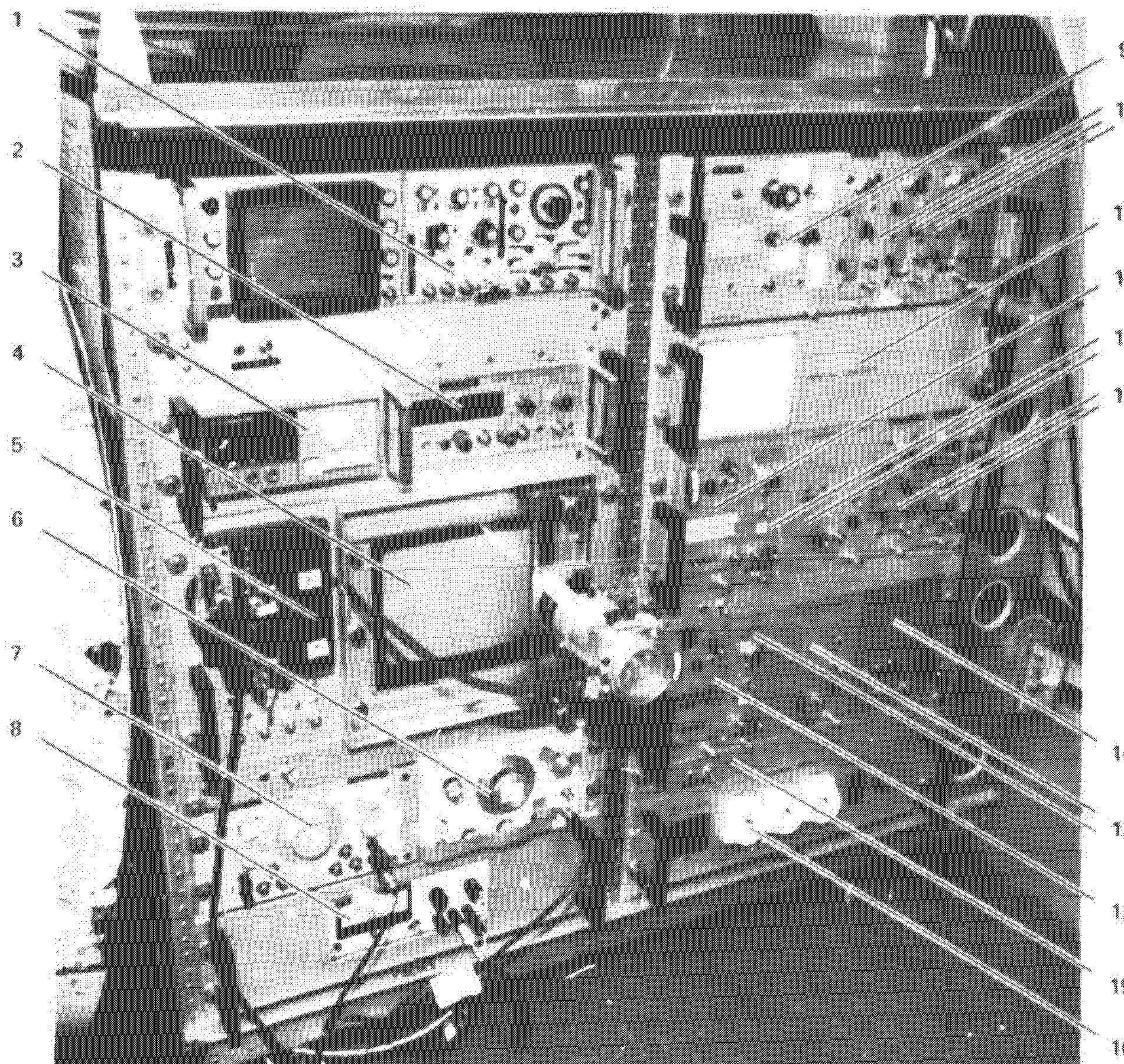
50-Hz INVERTER (FORWARD CARGO HOLD)

Figure B-17.- Meudon equipment configuration, right middle rack H.



1. DEWAR OPTICS CONTROL (FILTER/APERTURE) (GRONINGEN)
2. DEWAR ELECTRONICS CONTROL AND CHECK (GRONINGEN)
3. AMPLIFIER ISOLATOR (GRONINGEN)
4. A/D CONVERTER (MEUDON/GRONINGEN)
5. PULSE CODE MODULATOR (PCM) (MEUDON)

Figure B-18.- Meudon/Groningen equipment configuration, right rear rack I.



1. OSCILLOSCOPE
2. DIGITAL VOLTMETER
3. ELECTRONIC COUNTER
4. SERVO LOOP MONITOR/DETECTOR (BACKUP)
5. MONITOR SERVO LOOP TV CONTROL (BACKUP)
6. TELESCOPE SCAN Y FUNCTION GENERATOR
7. TELESCOPE SCAN X FUNCTION GENERATOR
8. FREQUENCY METER
9. SECONDARY MIRROR DRIVE AND CONTROL
10. SYNCHRONOUS DETECTORS FOR 5 GYROS
11. STAR FIELD DIGITIZER (PCM)
12. GYRO TEMPERATURE CONTROL
13. X AND Y AXIS GYRO MOTOR CONTROLS AND POWER
14. GYRO POWER SUPPLY
15. GYRO SIGNALS DISTRIBUTION
16. 28-V DC POWER DISTRIBUTION

Figure B-19.- Meudon/Groningen equipment configuration, rack J.

standard front panel method; the others were mounted on shelves in the rack bays — for example, 5 in figure B-17 and 5 in figure B-18.

Efforts to localize the most frequently adjusted controls of this experiment were generally successful: telescope controls were mounted on the rear of the rack H (fig. B-17), and the photometer/spectrometer controls were immediately to the rear on the forward side of rack I (fig. B-18). Unfortunately, this arrangement left no provision for regular aircraft seats from which to operate either rack. For some reason, the EO eschewed the use of a short stool (regularly available and frequently used to operate or repair components positioned near the floor; instead, he preferred to operate from a kneeling or sitting position. Telescope controls (fig. B-17) requiring the most frequent hands-on activities were located on components 1, 2, and 6. Most photometer controls (fig. B-18) were located on components 1 and 2. Photometer signals were recorded on the Ames stripchart (3 in fig. B-21), where they were annotated with experiment control settings, etc. The PI originally intended to control the tape recorder mounted on the lowboy rack (fig. B-16) from this central control area (component 3, fig. B-17). However, the central control circuitry did not function properly during experiment installation at Ames, and during the press of resolving much more serious problems the PI decided to forego this operational refinement.

The CV-990 flight environment brought about the addition of two unplanned components: two meters for monitoring telescope torque motor currents mounted just above component 9 on rack J (fig. B-19), and a stripchart recorder for monitoring aircraft roll mounted next to the closed circuit TV on top of rack H (fig. B-17). The former was installed during the resolution of the telescope aerodynamic buffeting problem, and the latter because frequently roll was large enough to cause the Meudon telescope to hit the stops. The roll signal was recorded on magnetic tape to allow the PIs to more conveniently unscramble the data taken during the periods of heavy roll. The stripchart recorder allowed the EO to diagnose guide problems more readily.

The size and number of electronic units associated with the Meudon telescope ruled out the incorporation of many rack-mounted backup components; there were backup servo loop components, however. Components 4 and 5 in rack J (fig. B-19) comprised a backup spot follower. The guide star image on the TV screen (4) was positioned before the star tracker type device mounted in front of the TV screen. In automatic mode, the servo loop acted to keep the star image centered before the tracker. Need for this backup did not arise. Groningen did not have any rack-mounted backup components.

Table B-18 provides additional information on the components of this experiment.

Experiment development and preparation- Table B-19 summarizes the development history of the telescope. Table B-20 lists the extensive modifications made for this mission to permit one-man operation. The construction schedule for the work performed on the telescope is given in table B-21. Equipment testing in preparation for this mission is listed in table B-22. During their training period, the ESA EOs spent little time at Groningen and so did not

TABLE B-18.- MEUDON COMPONENT INFORMATION

Component function	Construction	Power			Weight, kg	Cost, $ ×1000	Comments
		V	A	W			
Infrared telescope	Investigator-built						
Primary mirror						4.4	
Secondary mirror					210	1.11	
Optical train						1.33	
Mechanical train						5.56	
Inertial tracking system	Investigator-built + custom						
Oscilloscope	Custom	220		95	15	3.11	400 Hz
Frequency meter		220		28	4.1	0.67	400 Hz
Digital voltmeter		220		6	1.9	11.25	400 Hz
4 fans		220		160	5.6	.22	400 Hz
2 generators TBF		220		70	6.4	2	400 Hz
Power supply 28 V, 10 A		220		380	6	.89	400 Hz
Vibrating mirror assembly	Investigator-built + custom	220		---	3.7	2.67	400 Hz
5 synchronous detectors		220			10	3.89	400 Hz
2 temperature regulators		220			6.6	1.11	400 Hz
2 gyro motor supplies		220			2.8	.89	400 Hz
3 mounting racks	Custom					2.22	400 Hz
5 gyros (mounted)	Custom				5.4		
2 servo loops (X and Y)	Investigator-built + custom				8.2	1.11	
Gyro top supply					8	.67	
Tracker							
1 camera		220				9.11	50 Hz
1 connecting box		220			[illegible]	.89	50 Hz
2 monitors					20	.9	50 Hz
1 optical pointer					27	2.2	
Spot follower	Custom	220			12	21.1	50 Hz
Photoelectric cell	Investigator-built	220			4	.44	400 Hz
Automatization	Investigator-built						
PDP 11 computer	Custom						
Central processor		115			49.5	13.3	60 Hz
Auxiliary memory		115				8	60 Hz

TABLE B-18.- Concluded

Component function	Construction	Power			Weight, kg	Cost, $ ×1000	Comments
		V	A	W			
PDP 11 computer (contd.)							
AFR 33 teletype	Custom	115			2.9		60 Hz
Control + tape deck		115			48	15.8	60 Hz
Tape deck supply		115			36	8.56	60 Hz
Sundries		115				2.03	60 Hz
Terminal (visual)		115			19.5	9.82	60 Hz
PMC coder							
Multiplex		115			30	6.89	60 Hz
PCM decoder tape deck		115			22	15.8	60 Hz
Supply + filter					22		60 Hz
Analog recorder		220		65	22	8.9	400 Hz
Magnetic recorder		220		110	23	3.33	50 Hz
Cables	Investigator-built + custom				20	2.22	
50 Hz-28-V d.c. supply	Custom	28V		700	23	3.33	
Alco paper chart recorder		220		200	33	8.9	400 Hz
Output					15	0.67	
Sundries						2.22	
21 V engineering	Investigator					16.27	
7 scientific monitors						89.04	
General supply					18		
Commutation panel					7.5		
Command panel					8		
		Approximate totals			764	293	

TABLE B-19.- MEUDON EXPERIMENT DEVELOPMENT HISTORY

Experiment component	Initial develop- ment date	Earlier modifi- cations	Previous flights	Modifications for this mission (see table B-20)	Time involved in mission mods., man-years
Infrared telescope	1971	None	a	General check, elevation interface	6.5
Inertial tracking system	1971		a	One space gyro added, wiring, etc.	8
Pointing-TV camera	1971		a	More sensitive camera, scanner	0.5
Servo-control for long-term drifts (by TV signal)	1974		None	New	.1
Servo-control for long-term drifts (by photo call)	1974		None	New	.2
Manual selection and visualization of tracking	1973		a	More automation, new displays	--
PDP-11 computer, graphic display, teletype	1974		None	New	--
Analog tape recorder	1971		a	No change	0.1
Video recorder	1971		a	No change	--
PCM encoder and decoder	1974		None	New	--
Visualization oscilloscope	1971		a	No change	--
Voice intercom	1972		a	No change	--
50-Hz–28-V d.c. converter	1974		None	New	--
				Total	>15.4

[a]Over 20 flights in 1973 and 1974.

TABLE B-20.- MEUDON EXPERIMENT MODIFICATIONS FOR THE JOINT MISSION

<u>Power supplies</u>
Isolation transformer
28-V supply run off 400 Hz
50-Hz supply run off unregulated 28 V d.c.
<u>Pointing automation</u>
More sensitive camera
Change in tracking optics
Cam-driven mirror
Spot follower
A second monitor
Electronic servo-loop to reacquire the gyro derivatives by stellar tracking
Command centralization
<u>Onboard computer</u>
Central processing unit
Memory
Teletype
Tape deck
Terminal
<u>Date recording</u>
Differential amplifier
Multiplexing
PCM coder
PCM decoder
<u>Integration</u>
New mounting and wiring
<u>Scientific equipment</u>
Entirely refurbished

TABLE B-21.- MEUDON COMPONENTS DESIGN AND CONSTRUCTION SCHEDULE

April 1974	Selection of experiment Budget allocation
May 1974	Preliminary studies - interface, automatization Interface with NASA-Ames photometer Interface with Groningen photometer
June 1974	Experimenters meeting Selection of racks Report on Caravelle tests Final budget selection Reports on stress analysis, aircraft interface Selection of one of the scientists by CNES Choice of computer by CNES and experimenters Discussion on multichannel photometer (simultaneous) Choice of sequential mode
July 1974	Flight of the experiment on Caravelle
August 1974	Choice of computer
Sept.-Oct. 1974	New wiring definition Spot follower definition and order Computer software definition Selection of EOs
Nov. 1974	Test flight of photometer (mechanical and electrical interference) Ground testing of interface/study of IR offsets Selection of objects. First assessment of trajectories Selection of data-handling and -recording modes Writeup of experimenters' manual
Dec. 1974	Evaluation of test flight data Encoder wiring PDP-11 delivery delays due to factory mishandling of order Selection of 50-Hz converter for TV interface Training of a new PDP operator Ground loops and EMI problem examined - selection of Amplisation
Jan. 1975	Installation of experiment on the ONERA-LPSP test facility Implementation of components - wiring Pumping problem examined at Groningen - choice of motor
Feb. 1975	PDP-11 delivery at Toulouse (CNES) Software testing PDP-11 delivery at ONERA. Mishandling and repair Delivery of spot follower
March 1975	First tests of cryostat with complete interface Problems of diaphragm selection; cryostat revision decided General calibration of experiment General testing of software and experiment interface

TABLE B-21.- Concluded

April 1975	Week 1 Complete integration with photometers 1 and 2 Calibration with laboratory collimator Control of scanning mods Week 2 Training of EOs Write up of detailed checklists Week 3 Packing and shipment

TABLE B-22.- MEUDON HOME-BASE TESTING

Experiment component	Date	Type of test	Time tested	Test equipment used	Problem or highlights
Main telescope system	Nov. 1974	Flight test EMI Mechanical	2 hours	Record of noise U.S. diaphragm size	 None None
Cryostat subsystem	Nov. 1974	Laboratory alignment	3 days	Experiment standard equipment	Proper diaphragm balancing needed to cancel offsets satisfactorily
TV monitor and tracker – on artificial star – on real star	Jan. 1975	Sensitivity noise analysis	2 nights	Extra support for experiment	8th magnitude obtained
	March 1975	Calibration	1 week	Standard	As expected compatible with vehicle illumination
Computer	March 1975	Factory delivery Software interface Encoder/decoder (PCM)	2 days 2 weeks 2 days	--- --- ---	Illumination Debugging Satisfactory
Experiment (integrated)	March 1975	Offsets calibration mapping	3 days	1 collimator (laboratory made) 1 black body 1 large vacuum pump (100 m^3/hr)	Satisfactory Collimator optical setup corrected Few problems (cold mechanics) in cryostat Repair done at Groningen
Spare tracker (photocell)	March 1975	TV tracking + setup	1 day	None	Satisfactory
	Approximate total		28 days		

have the opportunity to gather detailed information on that portion of the experimental equipment.

Staffing and support requirements- Staffing and support for Meudon/Groningen are given in table B-23. Note that this experiment involved more different people than any other. The French team drew aid from scientific organizations other than the Observatory itself. More of the people involved in the total project also appeared at some time during the mission at Ames than on any other experiment. The Groningen PI, however, did not participate during the mission period at Ames.

TABLE B-23.- MEUDON INTERNAL AND EXTERNAL SUPPORT

Support organization	Specialty area	Contributions, man-years	Number of personnel	
			Scientists and engineers	Technicians
Observatoire de Meudon	Electronics Mechanics	9.1 0.5	5	3
Service des prototypes du CNRS	Design Mechanics	2.9 4.3	1	2
L P S P	Data system	---	2	0
CNES - Division Mathématique	Programing software	---	---	--
Société Lannionnaise d'Electronique	Electronics	1.2	---	---
University of Groningen	Astronomy Design Electronics	--- --- ---	4	2
			12	7

Ames Research Center

This experiment, titled Near Infrared Spectral Observations of Solar System Objects and Late-Type Stars, was sponsored by the Space Sciences Division, NASA/Ames Research Center. A scientist in the Theoretical Studies Branch was the designated PI, although the experiment was under the direct guidance of a colleague. The PI did not provide detailed information on the experiment. Consequently, this section does not provide the level of detail found in other sections.

The Ames PI proposed to NASA that he study several planetary atmospheres and Late-type stars using an improved filter-wedge spectrometer operating in the 4 to 24-μm range. NASA accepted the participation of the Ames PI in the Joint Mission, but failed to provide funding for the improved spectrometer. The PI therefore used an existing filter-wedge spectrometer that operates in

the 3 to 6-μm range, and concentrated his observations on α-Herculis, IRC+10216, the Moon (for calibration), and supplemented existing data on H_2SO_4 in the atmosphere of Venus with observations made in a different planetary phase.

Basic instrumentation- In the filter-wedge spectrometer, the band pass of a multiple-internal-reflection type filter depends on filter thickness. All the functions of a low-resolution spectrometer thus can be performed by passing the light beam being analyzed systematically through the thinnest and progressively thicker regions of the filter.

The Ames filter-wedge spectrometer is shown schematically in figure B-20. The spectrometer was mounted on the rear support plate of the Meudon telescope, alternately with the Groningen photometer. The filter wedge was closed on itself to form a wheel, which was rotated through the IR beam. The detector (indium antimonide, held at 77 K by a liquid nitrogen bath) operated in a photovoltaic (i.e., voltage- instead of current-generating) mode. Signals were processed by conventional means. The demodulated signal and filter position were recorded.

Equipment configuration- The Ames equipment is shown in figure B-21. It occupied only the inboard bay of rack I. Since the permanent data record was made by the onboard central computer facility (ADDAS), and a Meudon rack (H) contained the controls for automatic telescope tracking, only the spectrometer control, signal monitoring components and a signal amplifier/demodulator were mounted in the Ames rack. The installation included no back-up components.

Other than the controls in rack I the Ames EO had to contend only with the telescope tracking controls in rack H (immediately forward of rack I). Thus, the EO could reach all controls easily without moving from the space between racks H and I. However, as in the Meudon/Groningen case, the controls were most convenient to the EO if he knelt or sat on the floor.

Experiment Development and Preparation- As noted above, the Ames experiment flown during the Joint Mission was not the one initially proposed by the PI. The experiment actually flown was developed initially in early 1972 for astronomical flights on the NASA-Ames Lear Jet (30-cm telescope). It was flown frequently on the Lear Jet in 1972 and 1973; since mid-1974, however, it has been used sparingly, and components from the filter-wedge spectrometer had been removed for other uses. As a result, the experiment had to be partially reassembled and generally refurbished for the Joint Mission.

The equipment was far from ready at the start of the integration period. The acting PI and one of the EOs worked full time for two weeks to ready the equipment for installation. Their work was complicated by a misunderstanding about mounting dimensions for the spectrometer so that initially the instrument did not fit the Meudon telescope properly. An additional day's work was required to fit the instrument to the telescope.

Staffing and support requirements- The designated PI for the Ames experiment on the Joint Mission had not participated directly in the initial

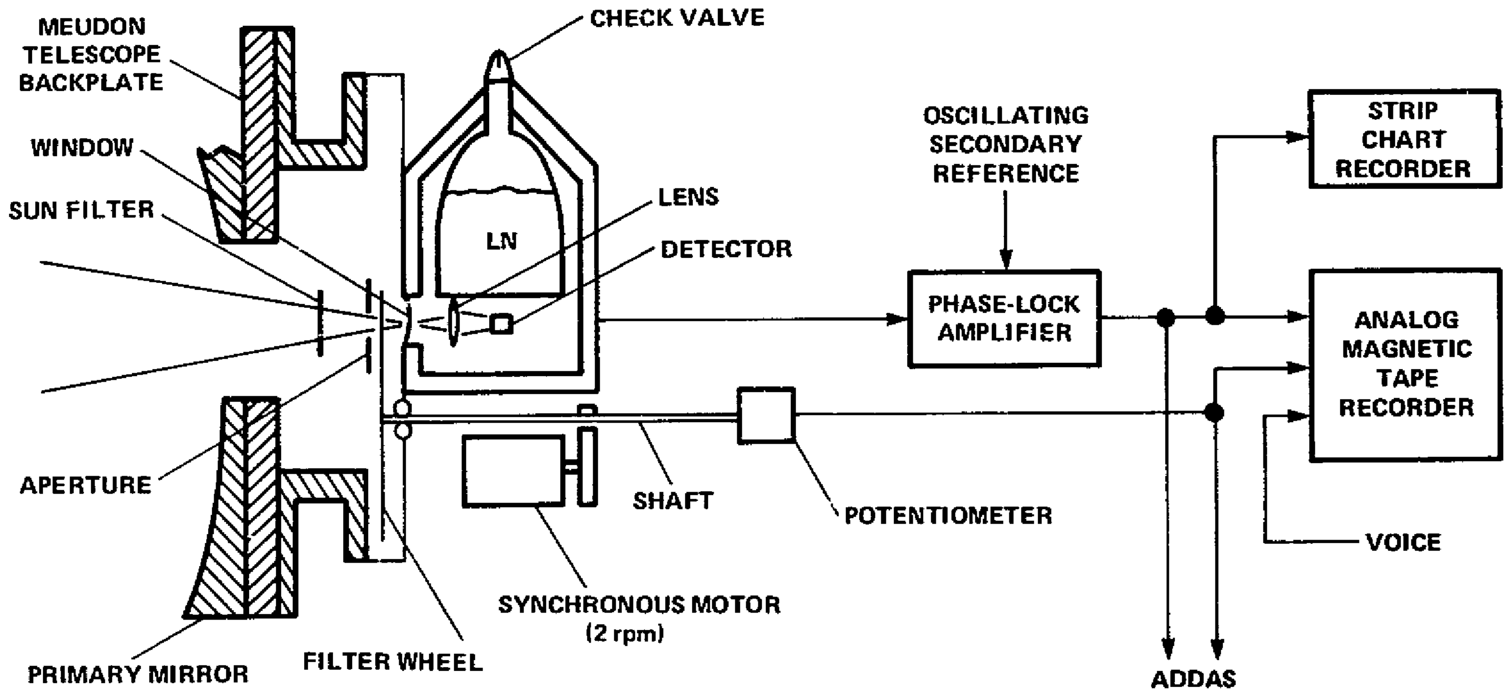


Figure B-20.- Simplified block diagram of Ames 3-6 μm filter wheel spectrometer.

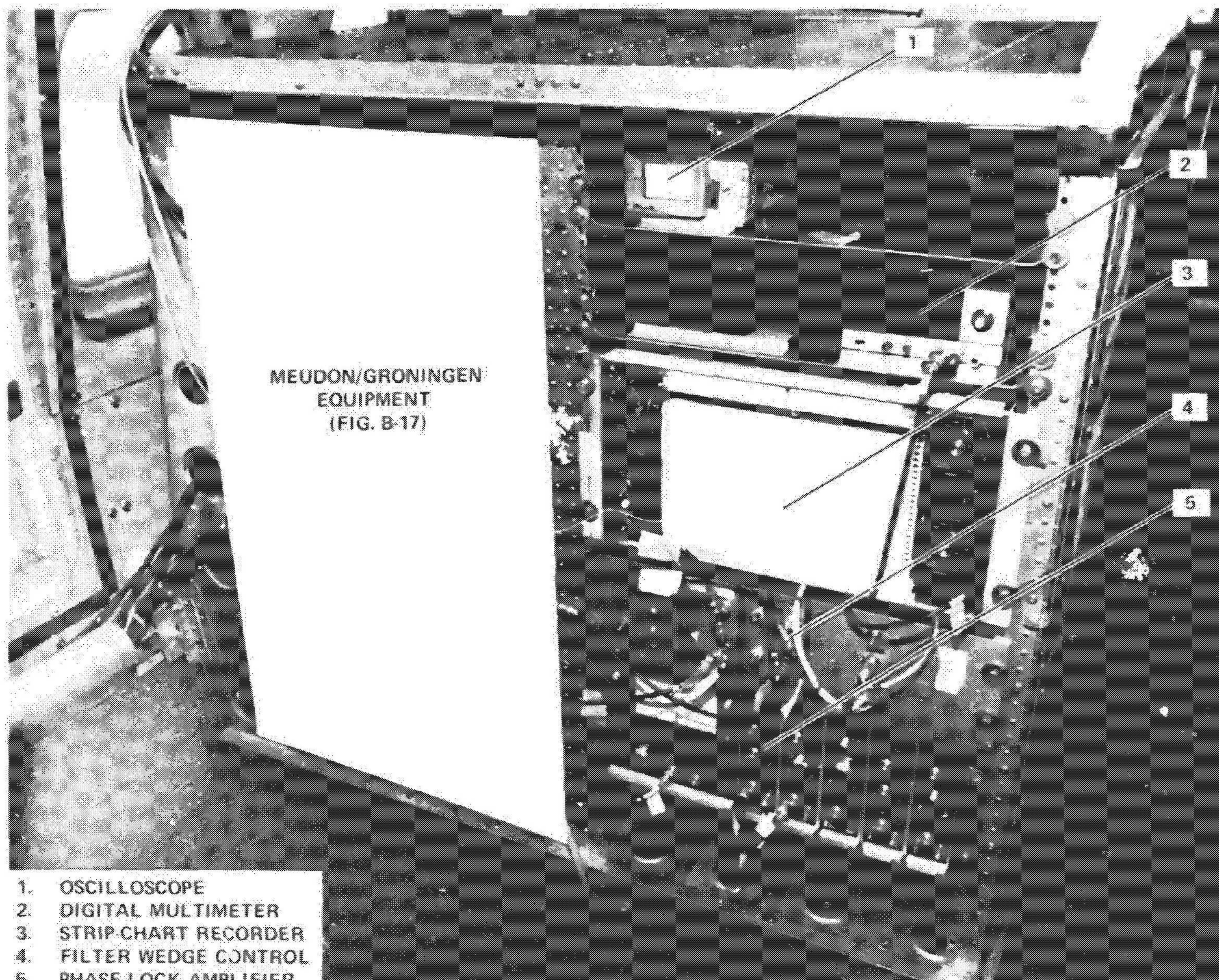


Figure B-21.- Ames equipment configuration, rack I.

development and operation of the filter wedge spectrometer in 1972 and 1973. The experiment was proposed, developed, and flown by members of an affiliated, but separate, group at Ames. In the proposal submitted by the PI for the Joint Mission, several members of this original team of scientists were listed as coinvestigators. The PI, a theoretician, relied on them for most facets of operational expertise.

NASA's refusal to fund an improved filter-wedge spectrometer coupled with an experiment flight schedule conflict led the PI to delegate all responsibility for flying the ASSESS filter-wedge spectrometer to his colleague. The PI's other experiment also took top priority in the in-house shops, so equipment construction for the filter-wedge spectrometer was not complete at the start of checkout and integration. Serious Level IV integration began about one month before the mission. During this time, the prime EO for the Ames experiment spent essentially full time with the acting PI as a de facto member of the experiment team in completing the installation and checkout of the equipment. This two-man team had no other technical assistance.

Jet Propulsion Laboratory

The JPL proposal was titled Near-Ultraviolet Airborne Spectroscopy of Atmospheric Phenomena, Solar System Bodies, and Stellar Objects. Actually, observations were carried out in the visible and near-infrared portions of the spectrum as well as the UV. This experiment and those from Alaska and Colorado, were initially intended to operate as a unified experiment under the direction of a JPL staff member as the PI. Unified operation of the three experiments was never attained, however, because of the conflicting demands of experiment development and other assignments on the JPL PI's time.

Detailed information on experiments requested of all participants was not provided by the PI from JPL. Consequently, this section does not provide as much detail as given for the European and New Mexico experiments.

The JPL proposal of July 1974 identified a number of intended objectives for the Joint Mission:

- Solar flux studies
  - Erythemal flux between 300 and 320 nm
  - UV spectrum between 290 and 350 nm
- Aeronomy studies
  - Atmospheric UV transparency at 14-km altitude
  - Twilight and night atmospheric OH emission
- Astronomical studies
  - UV spectrum of Venus, 294-360 nm
  - Study of interstellar molecules
    - OH transition, 306.4-317 nm
    - Search for NH at 336 nm

The JPL PI badly misjudged the difficulties of hand guiding a telescope on astronomical objects from a moving platform. Even with the telescope at

rest on the ground, some skill would have been required to keep an object properly centered in the field of view (the earth's rotation alone causes an object to drift through the field of view in approximately 30 sec). Thus, objectives that required guiding the telescope were abandoned until after the simulation period when a stabilized mirror was installed between the 14° window and the telescope. TAOF (tunable acousto-optical filter) observational objectives were pursued only halfheartedly because of the poor performance of these devices.

Basic instrumentation- Two separate spectrometers were set up, one for the visible portion of the spectrum and one for UV. Each involved a 20-cm Schmidt telescope, a TAOF, a photomultiplier as detector, and the associated electronic circuitry. One spectrometer/telescope assembly was positioned at a 14° elevation window in the aircraft and the other at a 65° elevation window.

The TAOF is a newly available commercial instrument of small size and good wavelength resolution. Figure B-22 is a block diagram of the TAOF and associated basic electronics.

Light enters window W, is brought to a focus at P . 20-cm telescope (not shown), is polarized by P, and enters an optically active crystal X. Light of one polarization, called ordinary, travels with velocity V_o in any direction in the crystal, while the velocity of light with plane of polarization perpendicular to the ordinary, called extraordinary, is a function of the direction of propagation in the crystal, and is generally different than V_o. At the other end of X, a piezoelectric crystal (PC) launches acoustic waves into X. The two sets of waves will interact if the relationship

$$\vec{K}_o = \vec{K}_e \pm \vec{K}_a$$

is satisfied, where $\vec{K}$ is a vector in the direction of propagation with magnitude $2\pi/\lambda$ ($\lambda \equiv$ wavelength), $\vec{K}_o$ is the wave vector for light of ordinary polarization, $\vec{K}_e$ the wave vector for light of extraordinary polarization, and $\vec{K}_a$ the wave vector for the acoustic wave. The plus or minus sign in the equation will apply in a particular interaction crystal. When interaction takes place, the plane of polarization of the light that satisfies the equation is rotated by 90°. Thus, if the light is reflected back toward P by M, P (if properly designed) will reflect the light with rotated plane of polarization and transmit all other light back through W. The reflected light is detected by a photomultiplier (PM). For each different frequency of the applied acoustic wave a corresponding light frequency satisfies the above equation so that by sweeping the acoustic frequency the spectrum of the incoming light can be determined. The filter bandpass is on the order of 0.1 nm.

Both TAOFs employed photon-counting circuitry. As the acoustic frequency was swept, the RF acoustic power was turned on and off at a rate (10-500 Hz) that would prevent saturation of the pulse-count register (determined primarily by signal amplitude). During the off half of the modulation cycle, the background of the instrumentation was counted. The EO had to enter test ID and calibration signals in the data record.

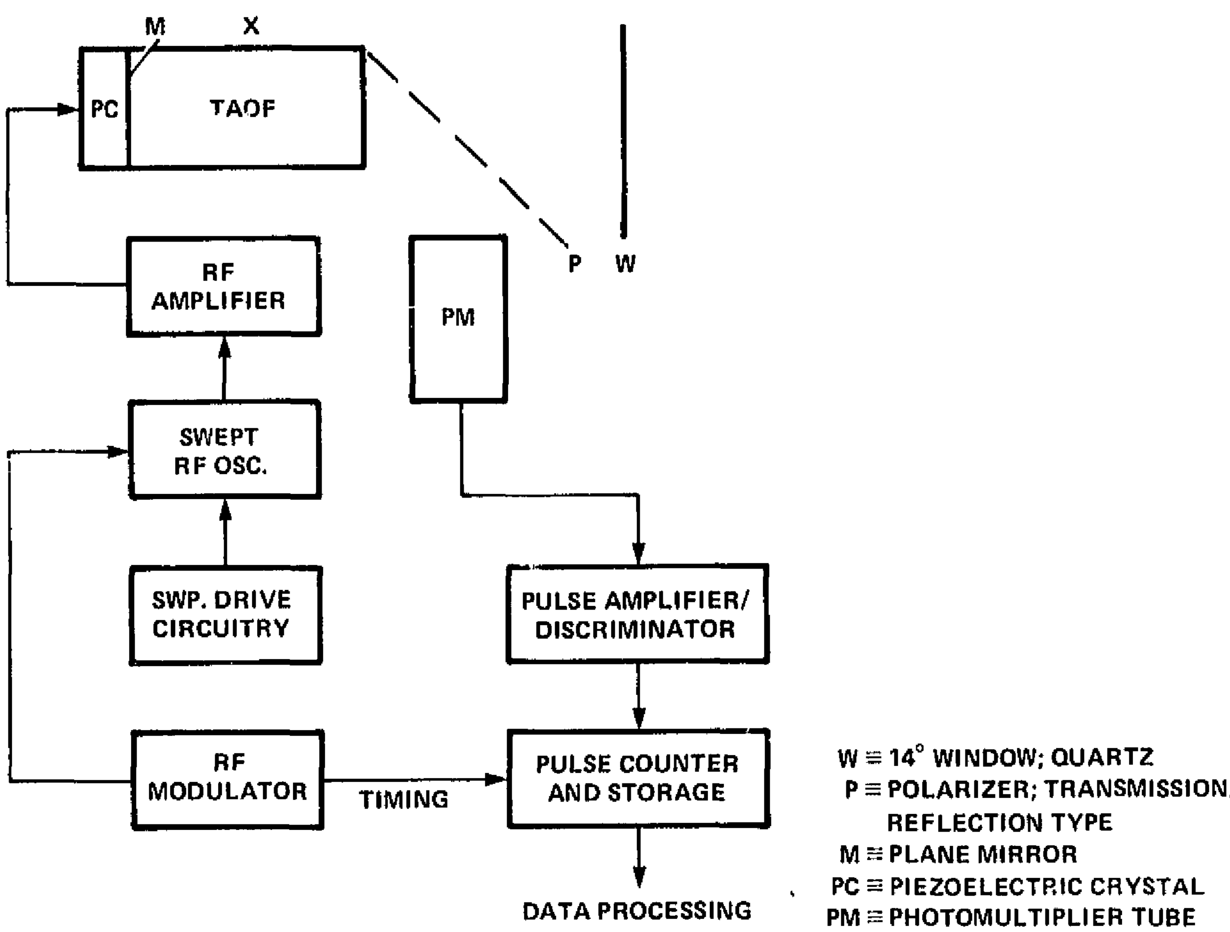


Figure B-22.- Block diagram of the JPL TAOF.

Equipment configuration- The configuration of the JPL experiment is shown in figures B-23 to B-25. The electronics rack (K) shown in figure B-23 contains controls and monitoring devices for two complete systems: two TAOFs, one operating in the near UV and the other in the visible region of the spectrum. However, during the check/EO training flights it was realized that the JPL/Alaska/Colorado experiment had to be simplified somewhat if it was to be operated by one EO. Thus, during the simulation mission only the UV TAOF at the 14° window was operated (fig. B-24). All visible TAOF components remained installed (fig. B-25), but the equipment was not turned on by the EO. After two simulation flights the turn-on operation was simplified still further by having the off-duty EO mount the UV TAOF and photomultiplier for the JPL/Alaska/Colorado EO. This work was done just after takeoff and took only two or three minutes, but the on-duty EO was especially busy with other turn-on activities at that time.

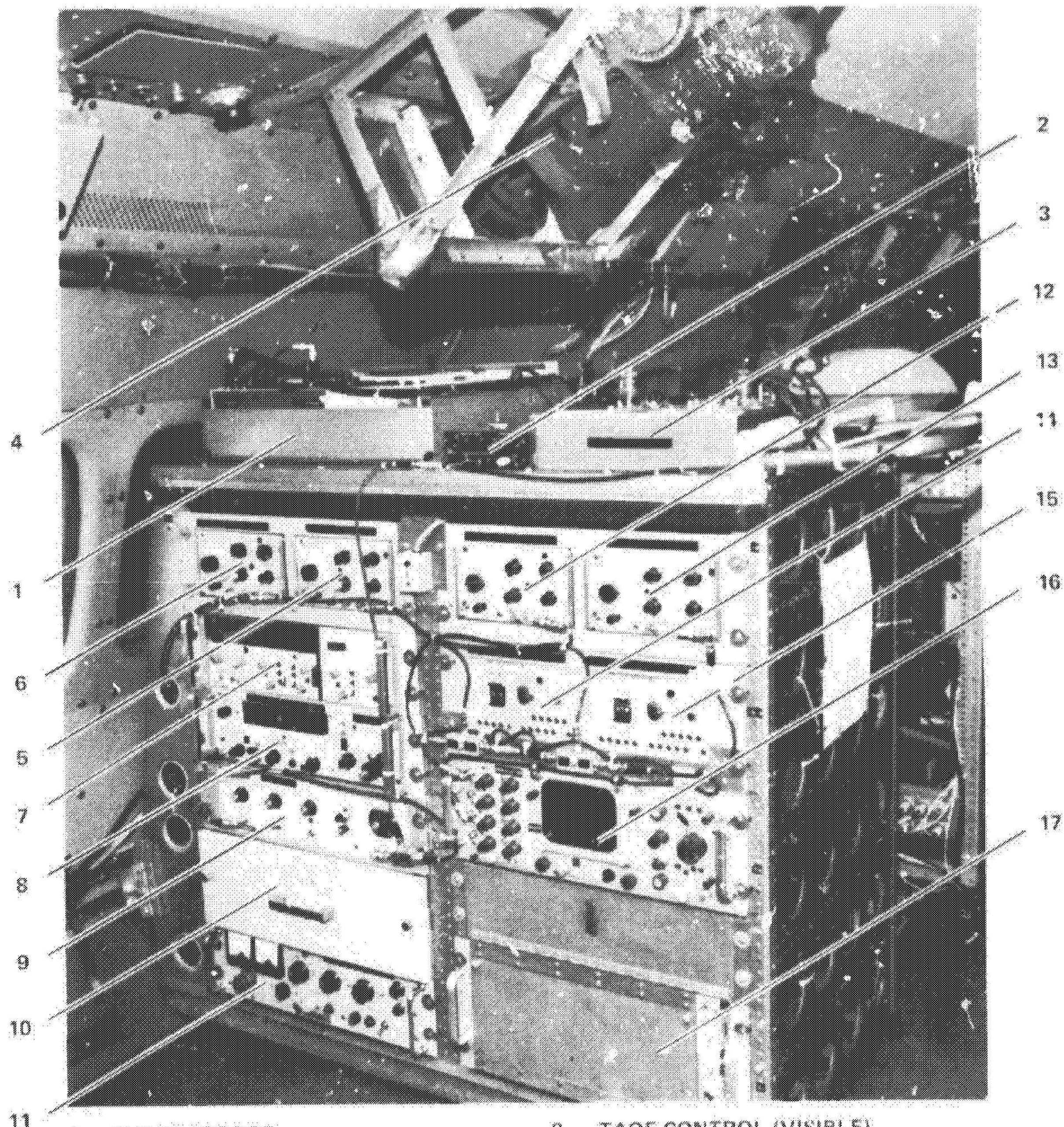
The visible and UV systems were almost identical except for details internal to the TAOFs themselves and the drive frequency. Since the visible system was not used during the simulation period, many of its components (5, 6, 8, 11, and 14 in fig. B-23) could have been used as backups for the UV system if needed. As it turned out the need did not arise during the simulation period. During a subsequent PI flight, however, 14 was transferred to the UV system.

The controls of the UV TAOF (10) were mounted quite low in the rack (fig. B-23). However, these were adjusted less often than modulation frequency and sweep ramp voltage (12 and 13), which were positioned conveniently in the rack. The high-voltage power supply for the UV photomultiplier tube (PMT) was contained in the PMT housing itself so does not appear in the rack. This PMT and data handling and monitoring were controlled at component 3. The EO made only representative copies of spectra on the X-Y recorder (1) — perhaps eight or ten per flight. Because of the requirements to reset start conditions, the X-Y recorder was more bothersome to operate than the usual stripchart recorder. (This was the first X-Y recorder observed in use by an experimenter aboard the CV-990.)

The JPL experiment was the only one that included provision (component 4) for making a voice record of the settings used and other pertinent information. The switch-activated microphone was attached to the top of the rack just to the right of component 3. The EO also hand logged on the X-Y record the conditions under which those spectral records were made.

Experiment development and preparation- Development of the JPL experiment was delayed by late delivery of the TAOF units. The visible spectrum unit was delivered early in January 1975, just a few months before the mission, and the UV unit was not delivered until after the start of the checkout and integration period. Thus, there was no opportunity at all for testing the UV unit in the laboratory at JPL.

The visible spectrum unit was set up in a laboratory at JPL on an optical bench for initial tests. Electronic equipment was gathered from the JPL instrumentation pool. Initially, the TAOF circuitry used was entirely analog



1. X-Y RECORDER
2. TIME-CODE READER
3. UV TAOF PMT CONTROL AND SIGNAL PROCESSOR/MONITOR
4. SCHMIDT TELESCOPE (STOWED POSITION)
5. SWEEP RAMP VOLTAGE GENERATOR (VISIBLE)
6. MODULATION DRIVE (VISIBLE)
7. FREQUENCY METER (UV)
8. FREQUENCY METER (VISIBLE)
9. TAOF CONTROL (VISIBLE)
10. DRAWER; LATER UV TAOF CONTROL
11. HIGH-VOLTAGE POWER SUPPLY (VISIBLE PMT)
12. MODULATION DRIVE (UV)
13. SWEEP RAMP VOLTAGE GENERATOR (UV)
14. D/A CONVERTER FOR ADDAS (VISIBLE)
15. D/A CONVERTER FOR ADDAS (UV)
16. OSCILLOSCOPE
17. STORAGE

Figure B-23.- JPL equipment configuration rack K.

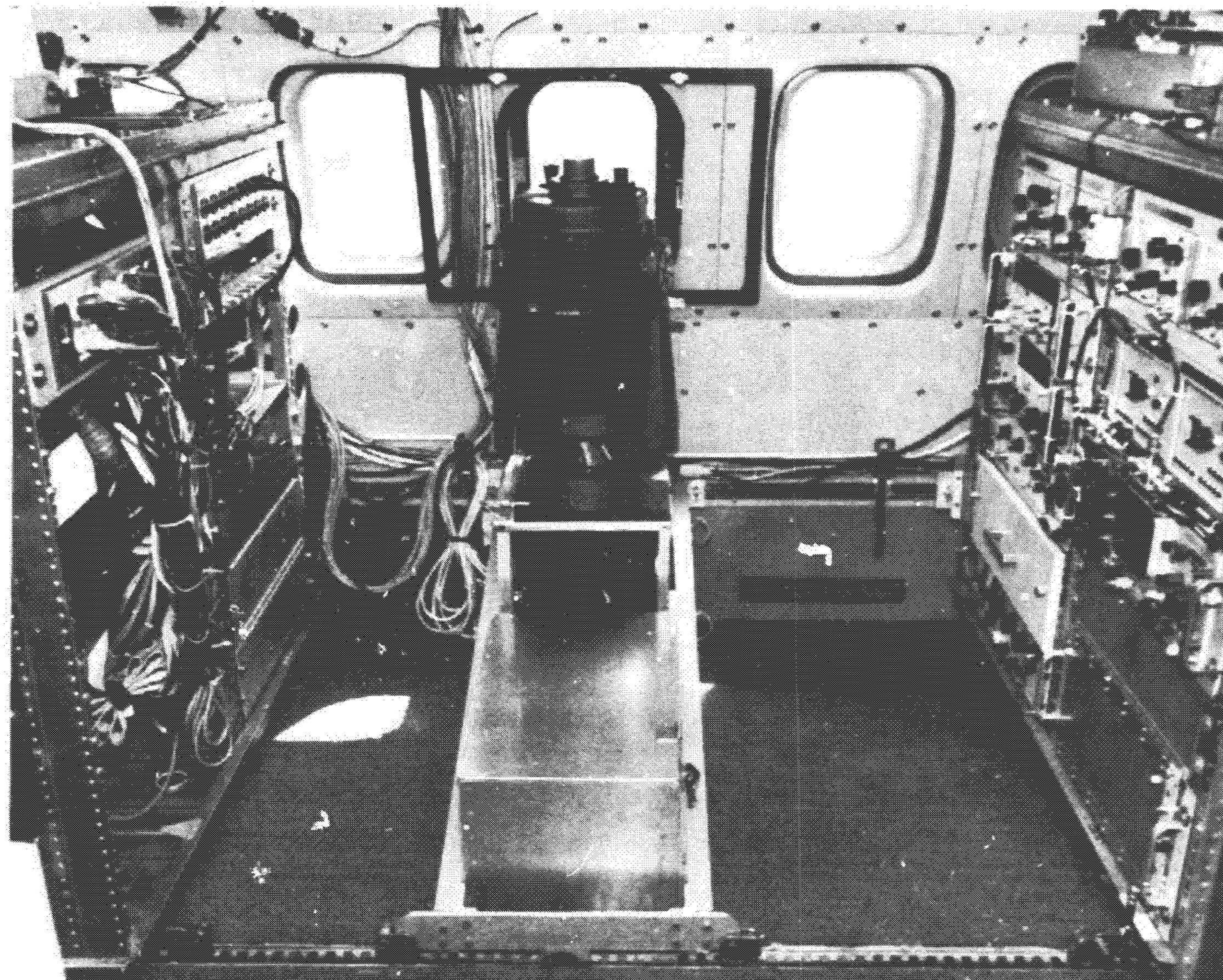


Figure B-24.- JPL Schmidt telescope at 14° window, in stowed position for takeoff. TAOF is stowed in box between telescope support rails. JPL rack at right.

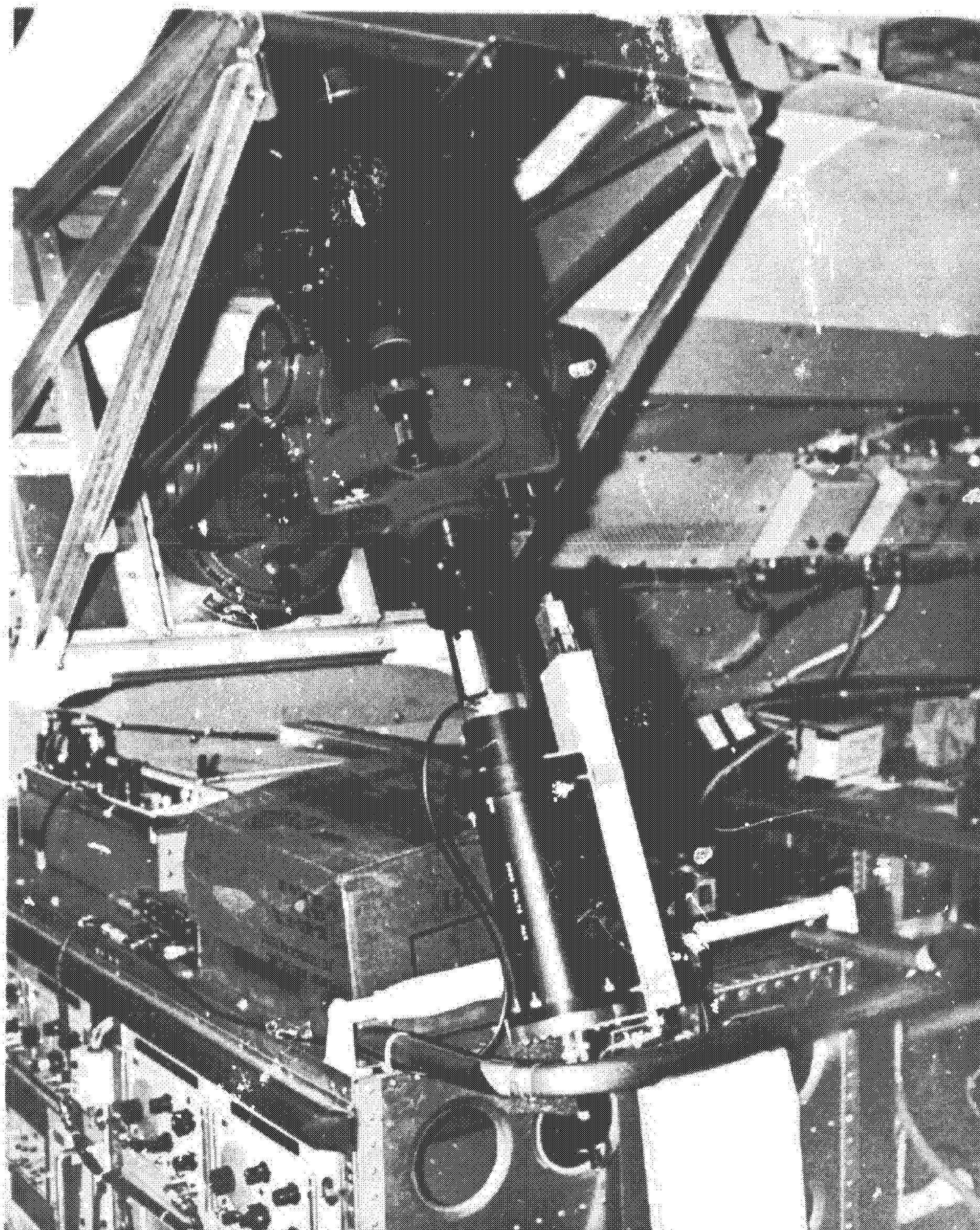


Figure B-25.- JPL Schmidt telescope with visible TAOF attached, mounted at 65° elevation optical window.

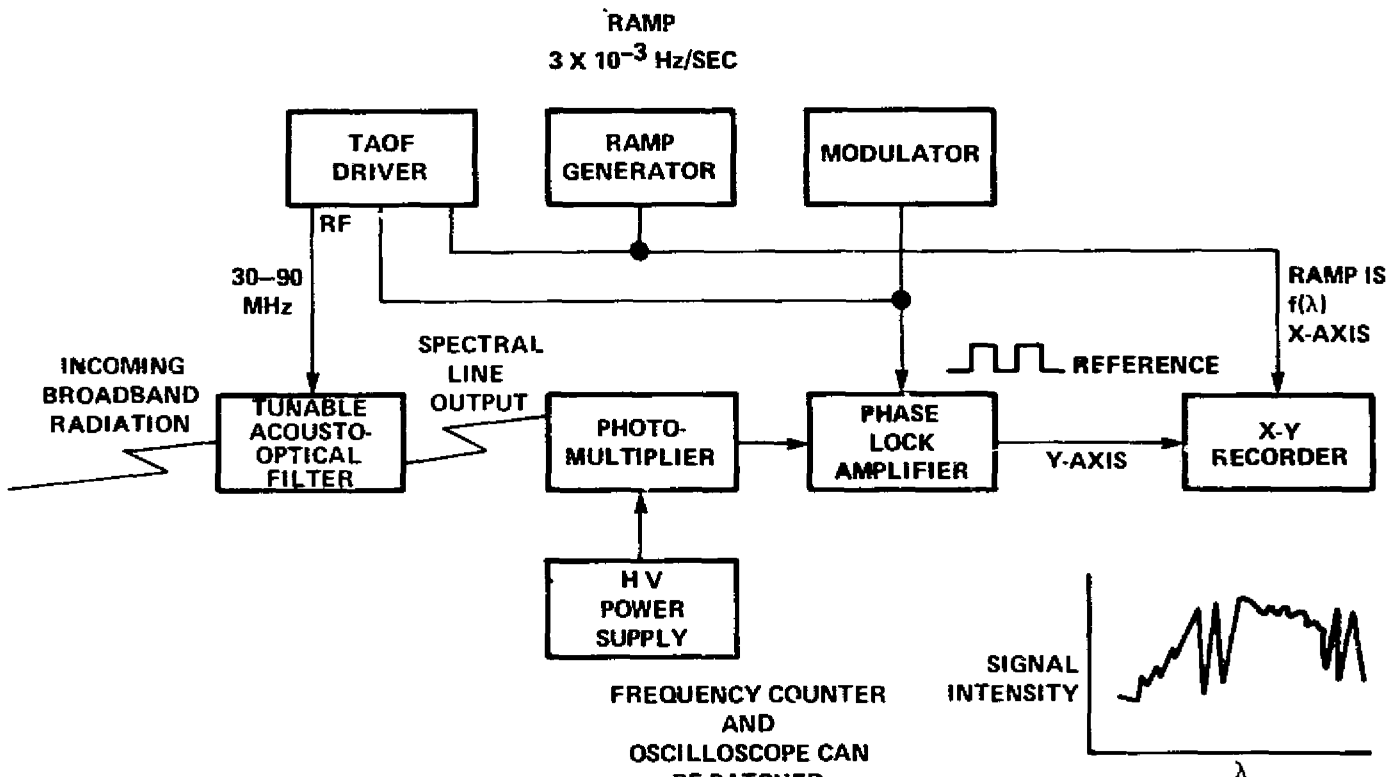
as shown in the block diagram of figure B-26. The equipment workable in the laboratory with various signal sources, all much more intense than the astronomical signals expected during the mission.

The visible spectrum unit with analog electronics was tested in the field on two separate occasions, one in February and one in March, at the JPL Table Mountain Observatory. During testing, the unit was attached to the 24-in. telescope, a much larger instrument than the 8-in. telescope planned for the aircraft installation. Operation on actual targets was sporadic, unpredictable, and seldom reproducible. Optical alignment appeared to be a large part of the difficulty. On one occasion, the output signal was unaccountably of the wrong polarity. During the first session at Table Mountain observation was abandoned in favor of additional checks with a neon lamp source. The second observation session at Table Mountain was cut short on the third day by a blizzard, which forced the team down from the mountain.

The visible spectrum unit was tested again in April on the 60-in. telescope at the McDonald Observatory in Texas. For this observation session, entirely new digital electronic circuitry had been developed and built hurriedly at JPL in an effort to reduce the noise level (fig. B-27). The equipment did not work well, and little useful experiment development resulted. Additional work was done at JPL before delivery of the equipment to Ames, but it fell short of the development and checkout status expected for that stage of premission preparations.

Staffing and support requirements- The PI was assisted by a senior mechanical technician, who was responsible for the construction of the optical components of the experiment and of all mounting fixtures except those made by the Ames shop to hold the telescopes. Another team member was an electronics engineer responsible for the second-generation digital electronics developed for this experiment. He and another engineer provided assistance at Ames in the integration period. Other JPL staff members provided occasional electronics design assistance.

The JPL PI was not able to spend full time on this experiment even though the equipment was late in delivery and time for development testing was limited. His assistant worked many long hours on the mechanical aspects of the experiment, and did fine machine work himself on the TAOF mounts. However, he was not trained as an optical technician, nor were the services of other optical technicians or optical engineers available to the experimental team. This lack of optical expertise is probably a primary cause of many problems encountered on this experiment. During the development of this experiment, it appeared that no one really knew whether the system was properly aligned at any time, or how to align it. Flight experience with the JPL experiment demonstrated that good intentions and even hard work are no substitute for the right kind of experimental expertise.



RF INPUT TO TAOF

$$f = \frac{a}{\lambda - b}$$

f in MHz
λ in μm

	a	b
450 nm $\leq \lambda \leq$ 650 nm	15.25	0.284
650 nm $\leq \lambda \leq$ 1.2 μm	15.48	0.2805

Figure B-26.- JPL TAOF analog block diagram.

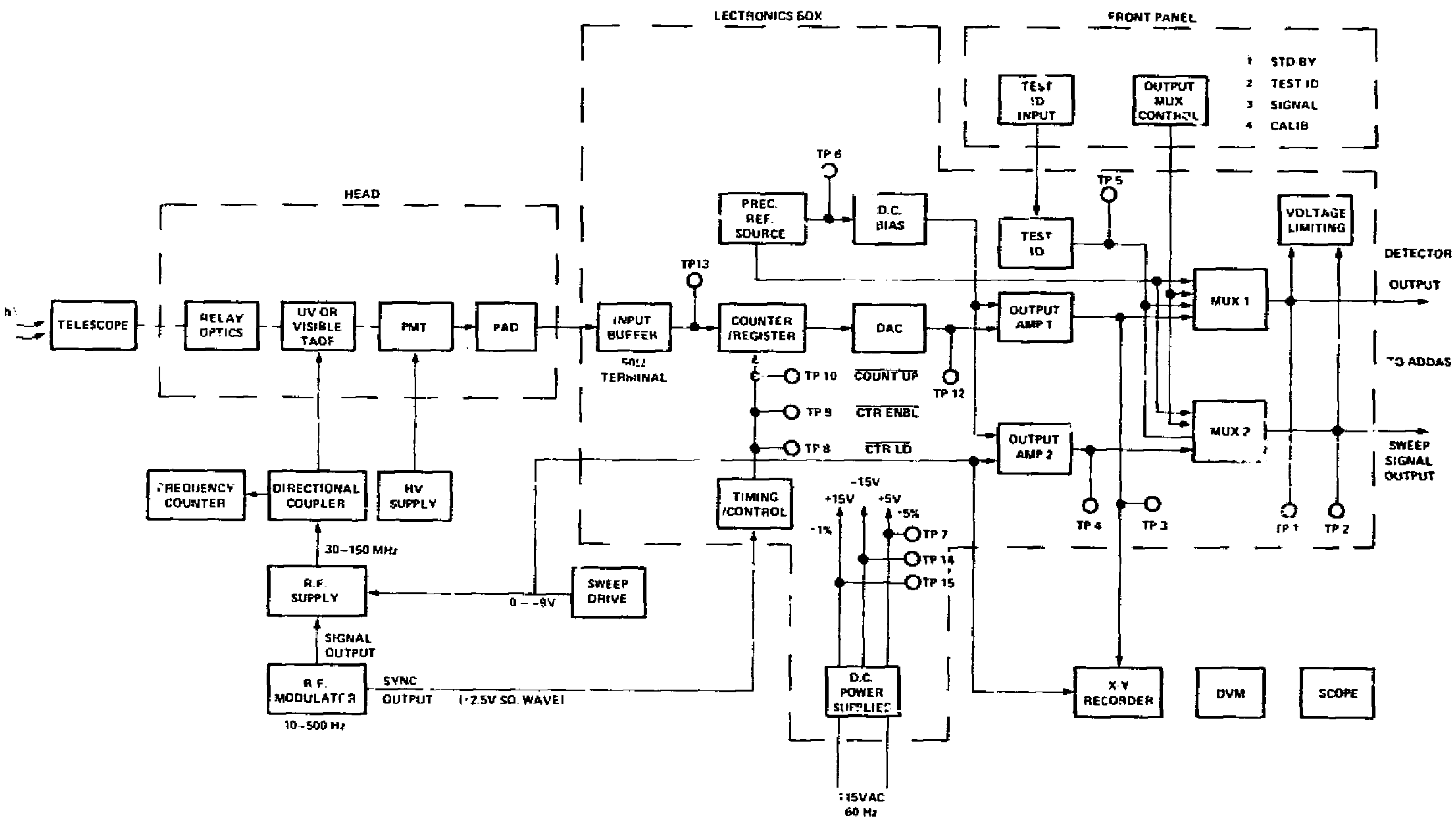


Figure B-27.- JPL TAOF digital block diagram.

University of Colorado

The JPL proposal covered the Colorado experiment but did not indicate that it would be operated separately. It was, in fact, a surprise to the Mission Manager when personnel from Colorado showed up with the instrument and indicated expectation to fly with it.

The Colorado portion of the experiment was intended to provide additional UV spectra of Venus and the night sky. Only a very small amount of information about this experiment was provided in the JPL proposal.

The JPL PI included the Colorado experiment in his proposal because he wanted independent data (from a proven system) of the type he was attempting to collect with the TAOFs. Such data would provide a basis for evaluating TAOF performance. No detailed comparisons of performance were made, however, because of the difficulties of hand-guiding a telescope on astronomical targets and the obviously poor performance of the TAOFs. Instead, the Colorado instrument was used primarily to view Venus and several stars in Scorpio (the latter during the PI flights) to determine how aircraft altitude affected the short wavelength cutoff of spectral data. Altitude effects on ozone and aerosol concentrations were also determined, but these were secondary objectives.

Basic instrumentation- The central component of the Colorado experiment was an Ebert-Fastie spectrometer that had been originally designed for space flight. Such intended usage made compactness and completely remote operation the principal design guidelines. The spectrometer had a focal length of only 12.5 cm, fixed slit widths, fixed sweep rate and wavelength range, and a non-filtered optical path. With all of these simplifications remote operation required only turning the spectrometer wavelength sweep on and off.

The Colorado experiment is shown schematically, without the telescope, in figure B-28. The spectrometer (top of figure) utilized two exit slits, S_2 and S_3, positioned so that light in the near UV passed through S_2 while visible light passed through S_3. In this way, data for two spectra, at 0.3-nm resolution, were taken simultaneously. (This was the only experiment in the Joint Mission complement with parallel data channels; all others involving more than one were operated serially.) The spectrometer was entirely under digital input/output control from the teletype keyboard. The grating was swept in a sweep/flyback mode, and the data, in the form of photon counts, were stored in a buffer; after a preset number of sweeps grating action stopped and the sum of spectra taken was recorded on digital magnetic tape. There was no modulation feature (as in the JPL experiment) to prevent the sum buffer from saturating. The program for experiment operation contained subroutines for real-time data analysis (see Appendix C, ref. 4), but these were never used by the EOs and only seldom by the PI.

Equipment configuration- The Colorado spectrometer was mated to two different telescopes during the Joint Mission: it time shared the Alaska 30-cm telescope as shown in fig. B-29 through the first nine flights, and was mounted on one of the JPL 20-cm telescopes for flights 10 through 14 (fig. B-30). The

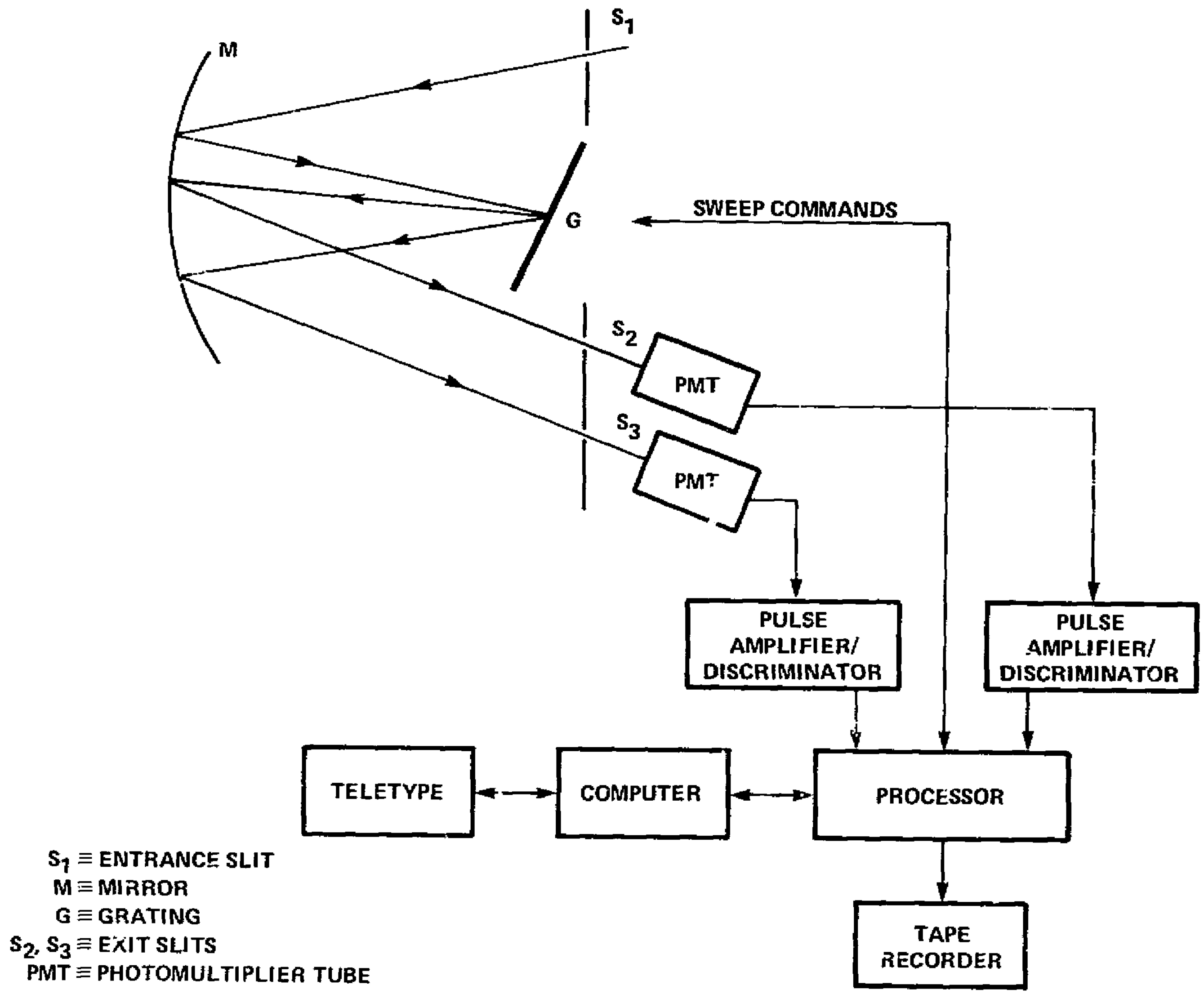


Figure B-28.- Block diagram of the Colorado experiment.

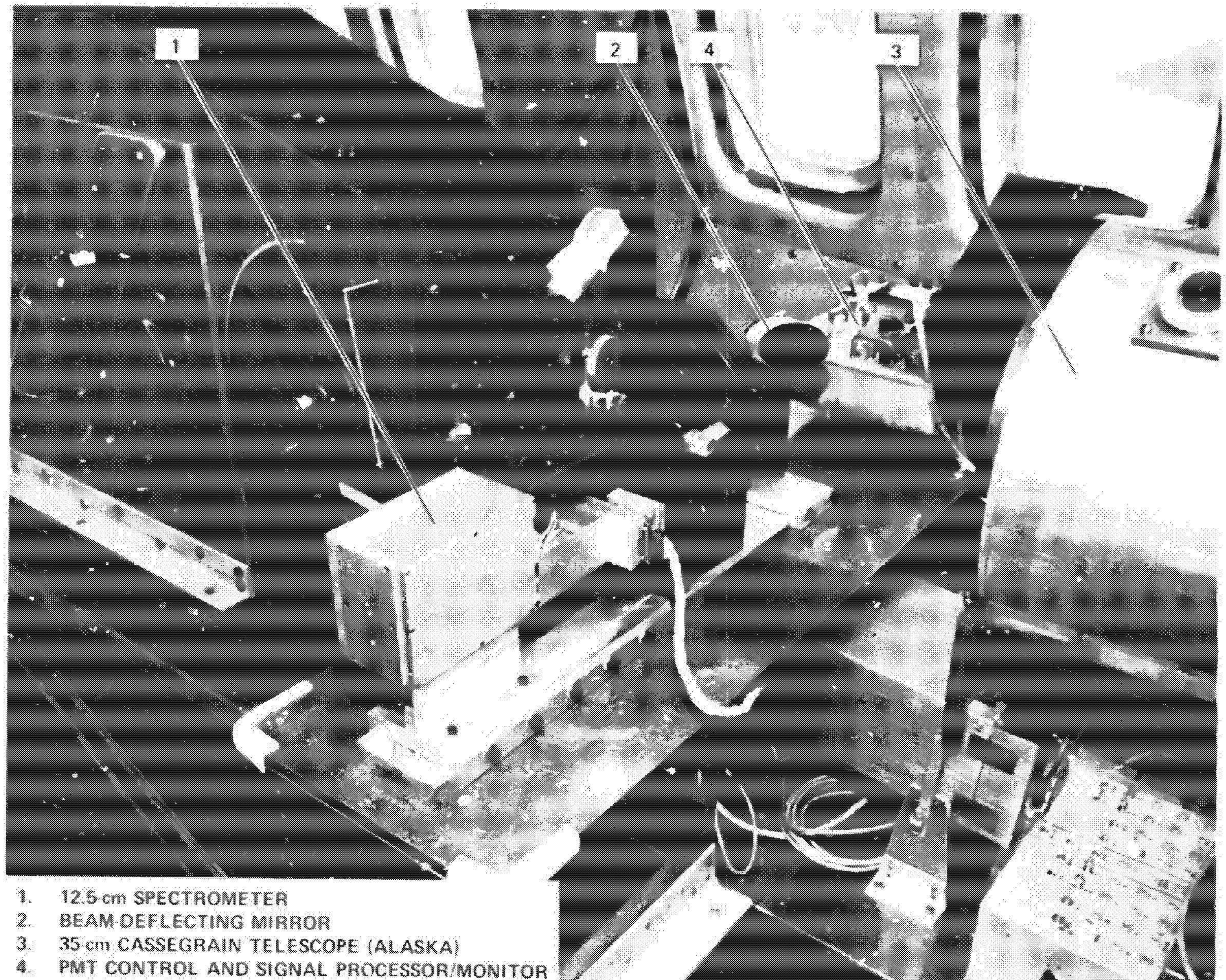
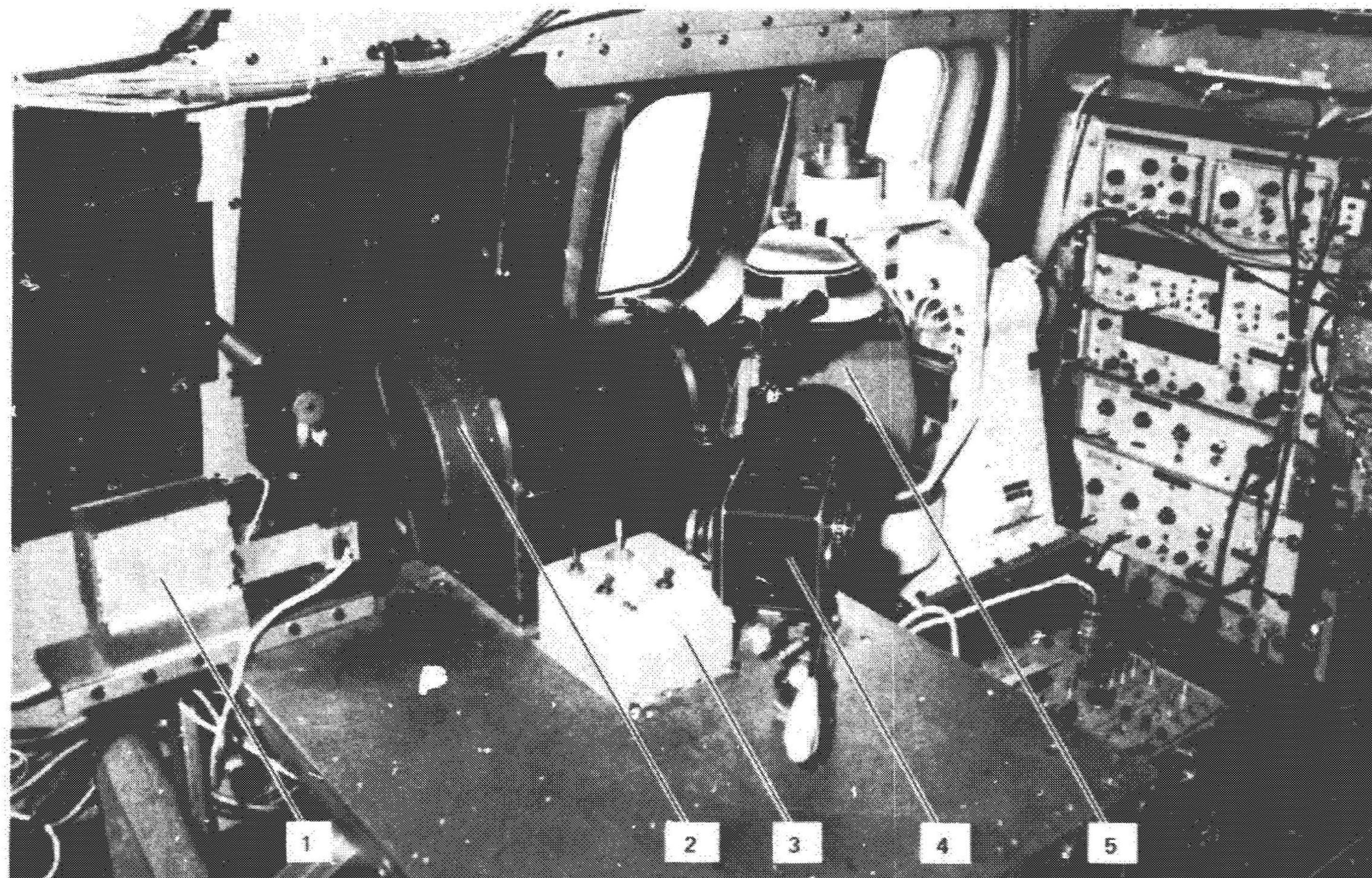


Figure B-29.- Colorado spectrometer in configuration for time sharing Alaska telescope.



1. 12.5-cm SPECTROMETER
2. SCHMIDT TELESCOPE
3. STABILIZED MIRROR MANUAL CONTROL
4. AUXILLARY 60-mm CAMERA
5. STABILIZED MIRROR

Figure B-30.- Colorado spectrometer mounted on JPL telescope, with gyrostabilized mirror.

JPL Schmidt telescope's configuration was also altered after flight nine to allow the insertion of the stabilized mirror (fig. B-30) into the optical path.

Other Colorado components shared a standard equipment rack (fig. B-31) with an IR radiometer installation (provided by NOAA), which was considered an aircraft system during the Joint Mission. The radiometers provided outside air temperature and water vapor overburden data, both of which are useful in interpreting astronomical data. All rack-mounted Colorado components were in or over the right-hand rack bay except for the single-channel stripchart recorder mounted adjacent to the teletype terminal (6 in fig. B-31).

As mentioned above, control of the Colorado spectrometer was completely remote. Once the individual components in the rack were powered up and the astronomical object acquired (see Alaska experiment discussion for details) 90 percent of the operational activities were carried out via the computer terminal (2). To simplify operation the PI purposely did not request real-time data-analysis options available in the computer program, which would have involved the EO more with the controls on component 3. The stripchart recorder was not used for quick-look information during data collection (component 3 contained a CRT quick-look facility). Instead, representative data on magnetic tape was read onto the stripchart after the flight to provide hardcopy downlink data for the PI. The experiment contained no rack-mounted backup components.

Experiment development and preparation- The 12.5-cm spectrometer is the prototype for the Pioneer Venus Orbiter UV spectrometer experiment. Development began in July 1973, slightly ahead of schedule to permit observations on the newly discovered Comet Kohoutek. However, even with an accelerated schedule, construction and testing were not completed until June 1974, well after the comet perihelion. Because of the accelerated schedule only operational, vibrational, and environmental testing were carried out on the prototype spectrometer. Operational testing was carried out (starting in March 1974) with the data-handling system used during the Joint Mission.

Between June 1974 and preparations for the Joint Mission, the system was used successfully several times on mountain-based telescopes. The experiment had been in an advanced state of development for about one year. Preparations for the Joint Mission therefore consisted only of the operational testing and the construction of bracketry required for mating the spectrometer to JPL or Alaska optical systems.

Final plans for integrating the Alaska/Colorado experiments were far from complete at the beginning of the integration period. Arrangements for beam interception to permit time-sharing the 35-cm telescope with Alaska were completed before the test flights began, but the arrangement was not satisfactory. The 35-cm telescope was of rather poor optical quality and it was optically matched to the wide-slit Alaska spectrometer, not the 12.5-cm Colorado spectrometer, which has a very narrow input slit. Consequently, following the simulation period, the Colorado experiment was reconfigured to time-share one of the JPL 20-cm telescopes with the UV TAOF. Greatly improved data were obtained with this arrangement.

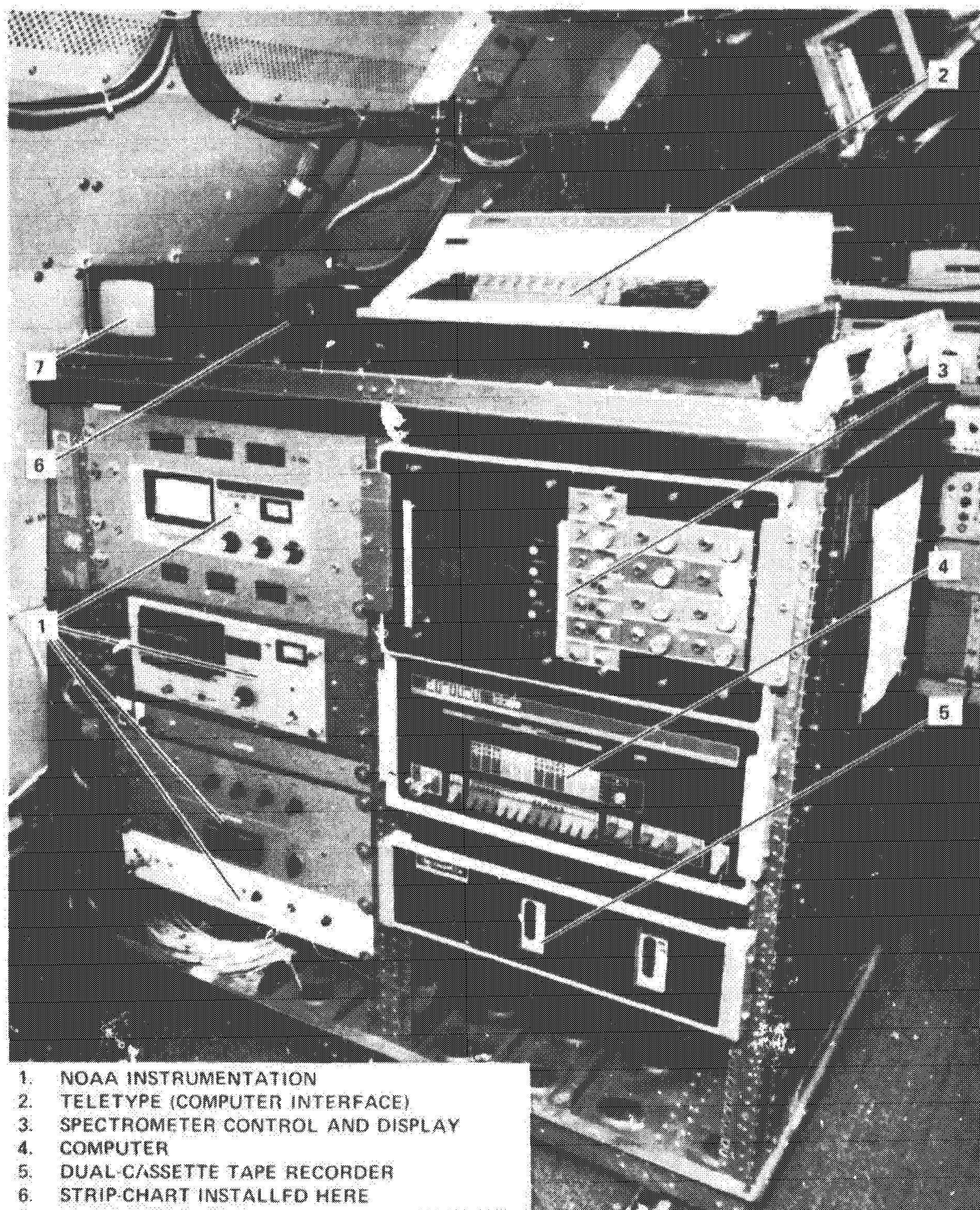


Figure B-31.- Colorado equipment configurati , rack L.

During the simulation period, operation of the Colorado experiment was simplified and only the least complex computer programs were used — those that summed spectra and recorded the results on magnetic tape. Many variations in programing were also available, which performed various aspects of spectral analysis in addition. The EOs were not requested to use these more complex programs.

Staffing and support requirements- The spectrometer (including the PMTs), spectrometer control, and first-stage data-handling components were constructed in the Laboratory for Atmospheric and Space Physics at the University of Colorado. The Colorado PI (a senior technician) was involved in the construction and testing of the instrument for the Pioneer Venus project. He also has been the principal operator in all applications of the instrument. The JPL PI was aware of the existence of the spectrometer and arranged with the University of Colorado for its use during the Joint Mission. The JPL PI was also responsible for the initial time-sharing arrangement with the University of Alaska telescope, an arrangement that allowed the Colorado spectrometer and the JPL TAOF to collect data simultaneously (for comparison of performance). The Colorado PI was critical of the quality of the Alaska telescope and the optical mismatch between the telescope and his spectrometer. He was instrumental in introducing the change in experiment layout whereby on flight 10 (after the simulation period) he began time-sharing the JPL 20-cm Schmidt telescope with the UV TAOF.

University of Alaska

It was planned that this experiment would be operated as part of a unified group of experiments comprising equipment from JPL, Colorado, and Alaska and under the JPL PI. Actually, it was operated separately from JPL, but did time share its telescope with Colorado through the first nine flights. At this point the Colorado experiment was reconfigured (see above), and the Alaska experiment became a completely separate operation. The coinvestigators were from the Geophysical Institute of the University of Alaska. They did not provide the detailed experiment information requested of all PIs.

The Alaska proposal listed four separate objectives, all involving studies of emissions between 290 and 750 nm:

- Studies of atmospheric constituents of Venus, Mars, Jupiter, and Saturn
- Studies of optical emissions from the terrestrial atmosphere
- Solar UV radiation at various altitudes
- Gaseous (atmospheric) pollutants

Basic instrumentation- The basic 1-m Ebert system is described in tables B-24 and B-25. The entrance telescope is a long-focal-length, large-aperture system (Cassegrain) to allow positioning of a planetary image on the spectrometer slit. The spectrometer's slit-plate lies in the focal plane of the Ebert mirror. Hence, light passing through the entrance slit is rendered parallel on reflection from the first half of the 16-in. spherical mirror.

TABLE B-24.- A BRIEF DESCRIPTION BY PARTS OF THE ONE-METER EBERT-FASTIE SPECTROMETER

Item	Description
Grating	Plane, 25.6 × 15.4 mm^2, 1200 lines/mm, 1.35 μm blaze, first order
Ebert mirror	16 in. diam, 1-m focal length, truncated spherical
Exit slit, PMT transfer optics	Internal reflecting axicon with convex spherical quartz lens
Order-sorting optics	Series of optical filters
Entrance and exit slits	Coupled, width adjustable 10 μm to 1 cm, length 15 cm, curved (radius of curvatures = 14 cm)
Grating drive	Motor-driven sine drive (coupling bar and sine cam)
Scan period	1 to 60 sec in increments by control of cam rotation
Free spectral range	1.5 to 570 nm by 10 weight-relieved cams
Detector	Photomultiplier tube (PMT) chosen for wavelength region
PMT cooling	Thermoelectric
PMT electronics	Pulse counting
Signal processing	Wavelength intervals and scan start addressed by pulses from grating drive for assembling and stacking in a minicomputer
Signal recording	Digital magnetic tape
Signal display	Storage CRT
Time	IRIG recorded on data tape

TABLE B-25.- WAVELENGTH REGION SELECTION BY GRATING ORDER

Diffraction order	Wavelength range, nm	Linear dispersion, nm/mm
1	991-1547	0.58-0.16
2	495- 773	.29- .08
3	330- 515	.19- .05
4	247- 386	.15- .04

The parallel beam is diffracted by the grating and focused onto the exit slit by the second half of the Ebert mirror. At the exit slit, a light pipe, formed by cementing a field lens to a reflecting pyramid, reduces the diverging output beam to a 14-mm-square cross-section and delivers it to the cooled photocathode of a photomultiplier tube.

A linear wavelength scan on the spectrometer is produced by a sine drive, which consists of a coupling bar and a sine cam driven by a stepping motor. Electronic control of the stepping rate allows a choice of different cam-rotation periods from 1 to 60 sec, while a set of 10 cams permits a choice of wavelength-scanning intervals.

Detection of low-level signals necessitates scan summation, which in turn requires accurate scan initiation, if a smearing of the signals is to be avoided. An optical pickup system is used to provide an accurate initiation pulse during the grating flyback. Both the sync and the photo pulses are fed

to a buffer and into the rest of the electronic system described in the block diagram of figure B-32.

Equipment configuration- The Alaska experiment was distributed on both sides of the aircraft aisle (fig. B-33) with optical elements on the left and most electronic components on the right. The optical assembly is shown in views taken from fore and aft in figures B-33(a) and B-33(b), respectively. The control for the thermoelectric cooler, which maintained the photomultiplier tube (PMT) detector at reduced temperature, was mounted on a floor pallet between the spectrometer and the port-side aircraft frame structure. It remained on at all times and required no attention from the EOs. Star-tracker controls were mounted just below the tracker detector at the rear of the telescope, convenient to the coarse guide optics, and the digitizer of the spectrometer output signal was mounted on the cooled PMT detector housing to keep analog signal cable lengths to a minimum. The experiment included a stabilized mirror (heliostat) with its control electronics mounted between spectrometer and frame, just aft of the cooler control (fig. B-33(c)); this device was operated by an Ames technician throughout the mission. The EOs only manipulated mirror position, after the technician had readied the system for operation. The technician also recorded calibration signals (on ADDAS magnetic tape) for mirror position, and secured the system as required.

The distribution of electronic components in the right-hand rack (N) is shown in figure B-33(d). Items 1, 2, 3, 6, and 7 were pallet mounted; items 8 and 9 were bolted to the right-hand panel mounting flange. This rack was one of only two that had regular passenger seats positioned so that the EO could sit while operating the experiment. Thus, controls near the floor were reasonably accessible. Only components 4, 5, 6, and 7 had controls that might need adjustment at the start of any given data leg, and by far the most activity centered on the interactive computer terminal (4). Planned operation of the Alaska tape recorder, which was located in an awkward position on the forward side of the rack, required only loading computer program and data magnetic tapes at the recorder, with all other functions controlled via the computer terminal. The tape recorder malfunctioned during the check flights and was removed for repairs prior to the start of the simulation mission. It was returned to the aircraft between the second and third simulation flights, but in accordance with the mission rules, it was not operated by the EOs. It was planned that the onboard central computing facility (ADDAS) would be a backup to the experiment's data system. After the tape recorder malfunctioned, the ADDAS became the prime data logging system; as backup during the simulation period, the signal (in analog form) was sent to a magnetic tape recorder peripheral to the ADDAS. The experiment installation included only one rack-mounted backup component — a signal averaging device (3), which could be substituted for the computer controlled averaging normally used.

Spectrometer sweep center and sweep width were fixed by mechanical controls on the spectrometer. The EO took several minutes to change from one set of conditions to another, a procedure that was performed, generally, two or three times each flight. Other parameters directly affecting data quality (slit width, integration time, PMT voltage, etc.) were set with controls in component 6 in the right-hand rack.

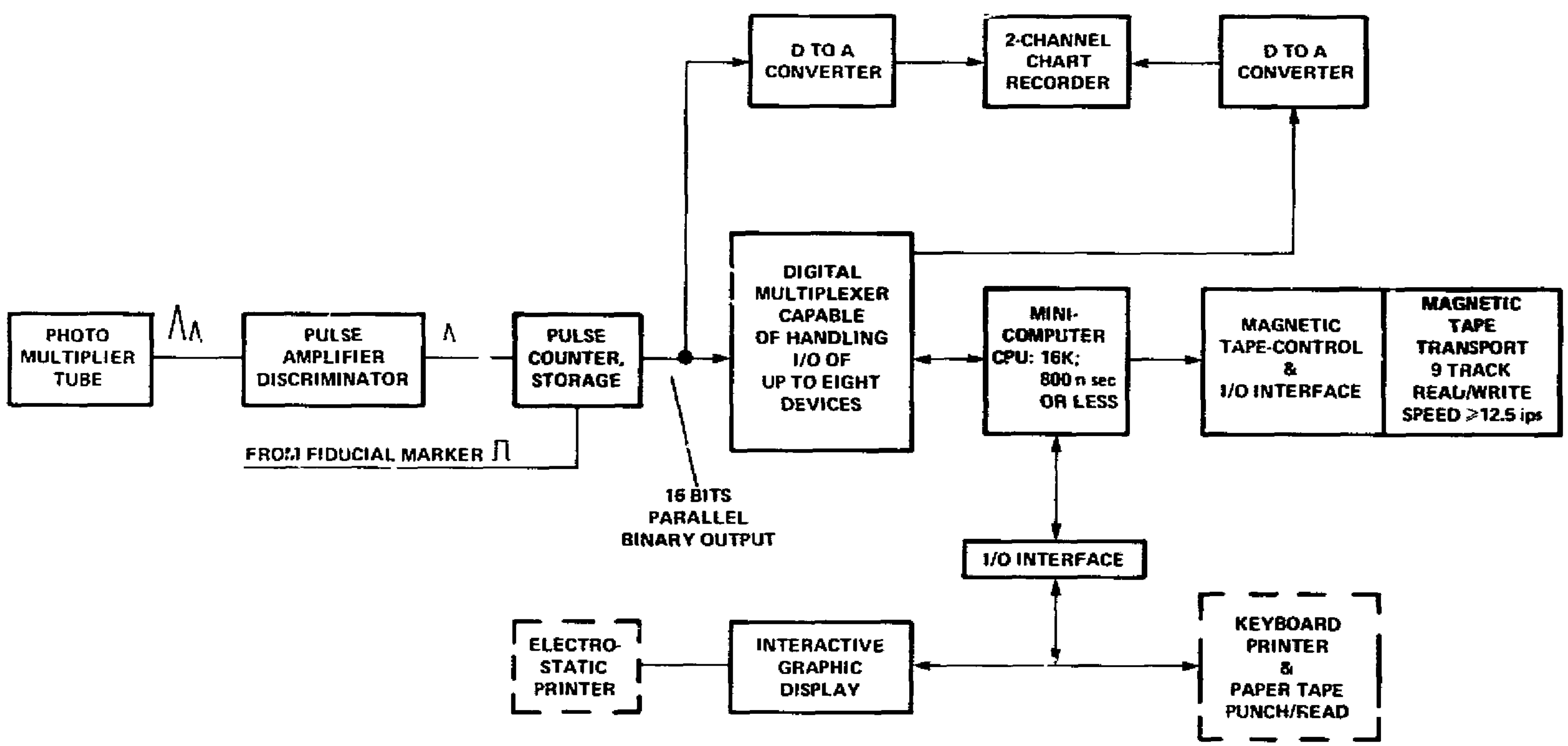
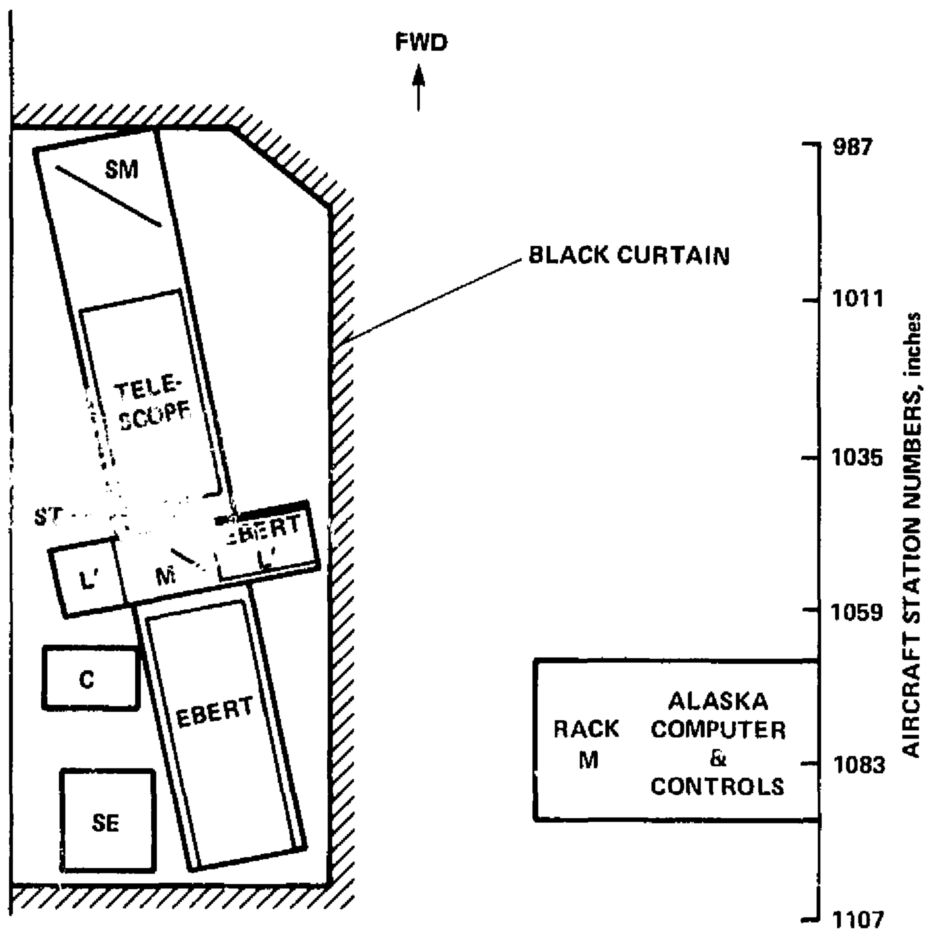


Figure 32.- Alaska electronic data recording and reduction system.

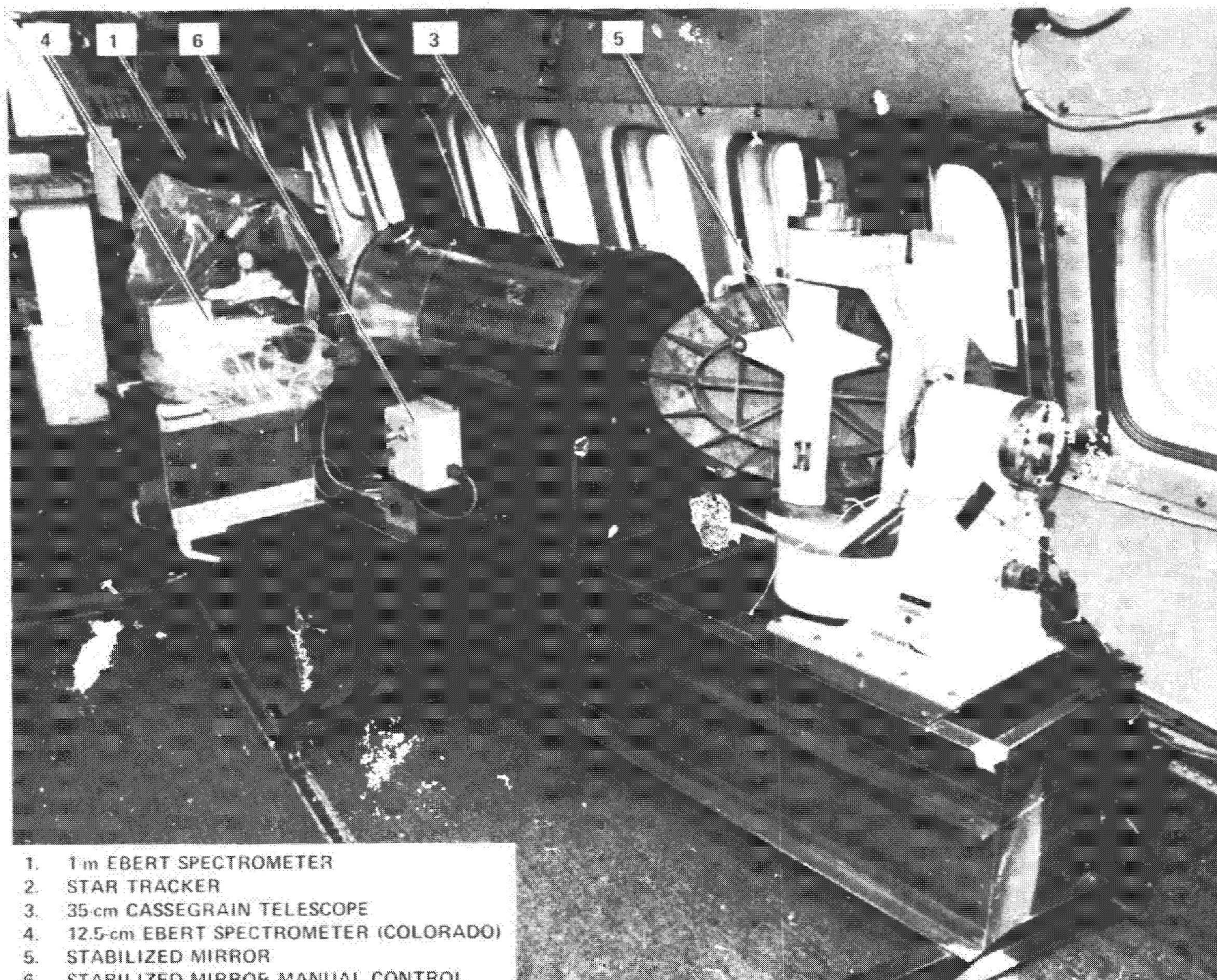


SM ≡ STABILIZED MIRROR
M ≡ PLANE MIRROR (REMOVABLE)
ST ≡ STAR TRACKER
L' ≡ COLORADO EQUIPMENT ASSOCIATED WITH RACK L
C ≡ PMT COOLING CONTROL
SE ≡ STABILIZED MIRROR ELECTRONICS

(a) ALASKA EXPERIMENT FLOOR PLAN

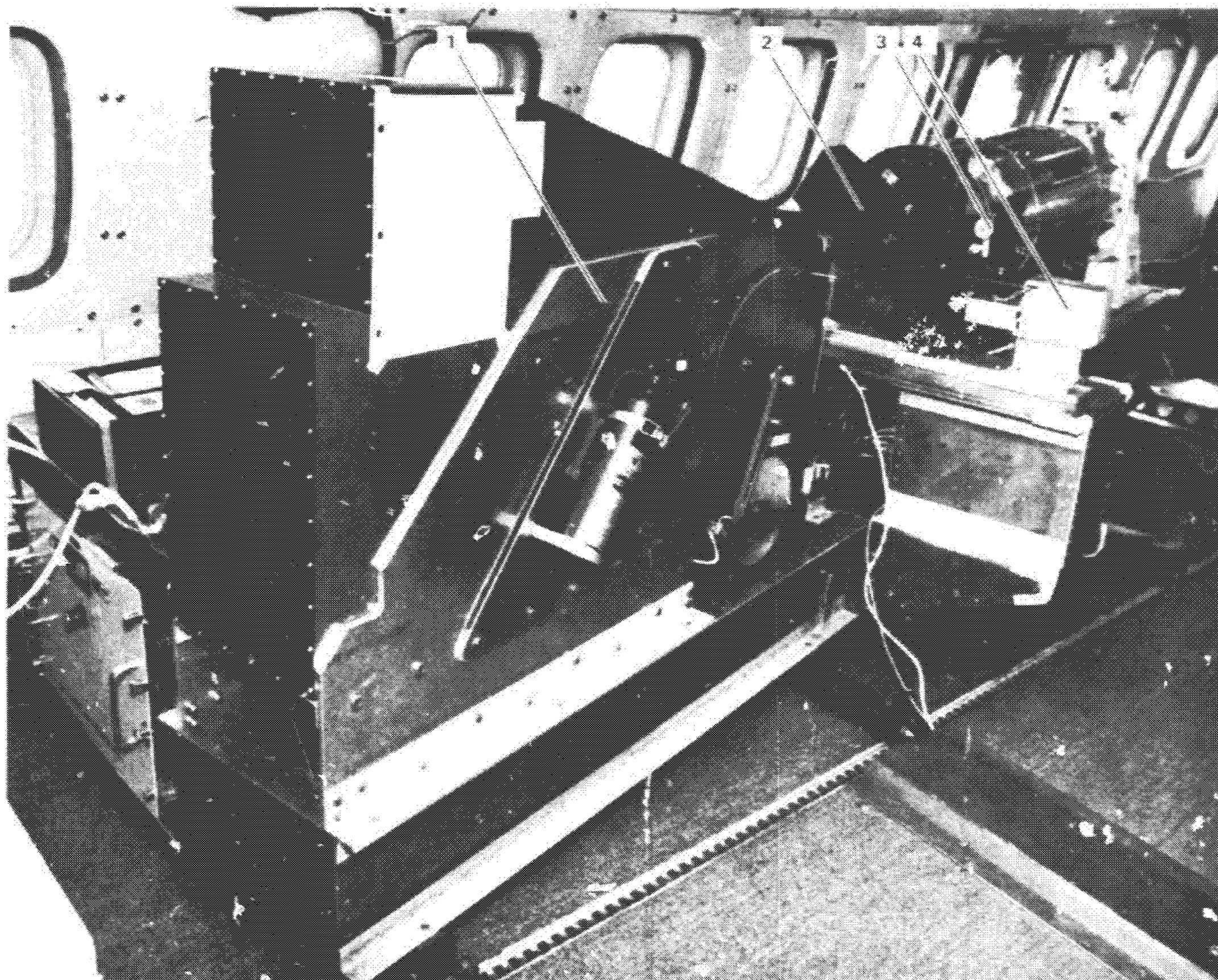
(a) Alaska experiment floor plan.

Figure B-33.- Alaska experiment.



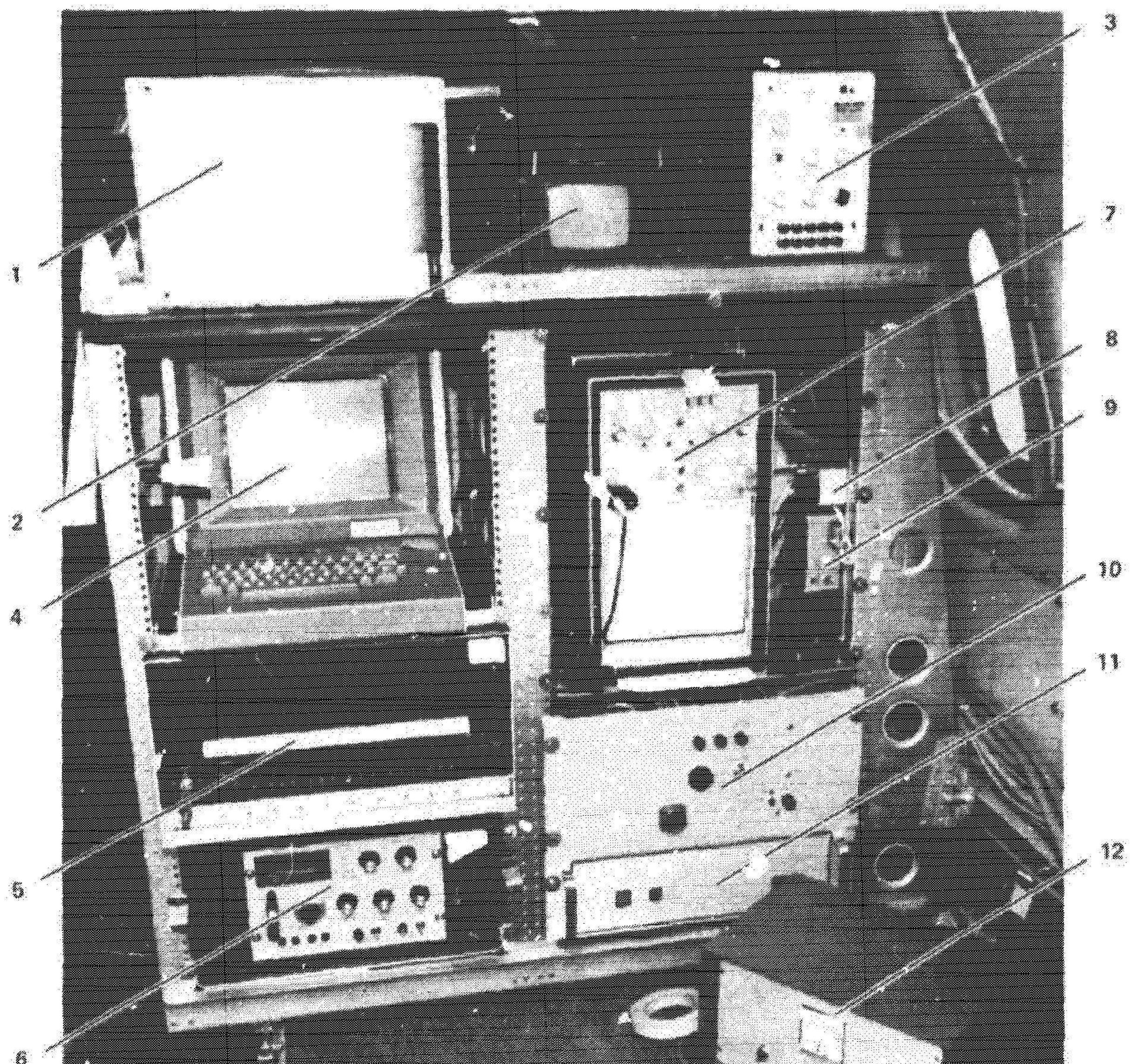
(b) Forward view of Alaska optical bench.

Figure B-33.- Continued.



(c) View of Alaska optical bench from aft.
See figure B-33(b) for component identification.

Figure B-33.- Continued.



1. COMPUTER DISPLAY TERMINAL CONTROL
2. CLOSED-CIRCUIT TV (AIRCRAFT PARAMETERS)
3. SIGNAL AVERAGER (BACKUP)
4. COMPUTER INTERACTIVE TERMINAL/ DISPLAY
5. COMPUTER
6. SPECTROMETER CONTROL
7. STRIP CHART (2 CHANNEL)
8. ASO TIME CODE/EXPERIMENT DISTRIBUTION BOX
9. D/A CONVERTER ADDAS INTERFACE
10. MULTIPLEXER
11. DATA FORMATTER
12. PMT COOLING CONTROL (INSTALLED BEHIND SPECTROMETER FOR FLIGHT - SEE FIG. B-33)

(d) Alaska electronics in rack N.

Figure B-33.- Concluded.

The experiment computer controlled data collection but not action of the spectrometer itself, which swept in a continuous sweep/flyback mode. The computer program allowed the real-time summation of a predetermined number of spectra and the printout of the sum by the ASO hard-copy unit. The program included other subroutines for real-time analysis, the heavy EO workload precluded their use.

The telescope used in this experiment initially was part of a rocket guidance system. As such, its optical quality was less than desired for the present application. However, the budget for this experiment did not allow the purchase of a more suitable instrument. To convert this telescope into an astronomical instrument, the Alaska PIs introduced a beam splitter that diverted about 10 percent of the light to the star-tracker unit, thereby reducing considerably the capability of locking onto dim objects. The Alaska PIs also introduced a coarse guidescope. The line of sight of this device was peripheral instead of axial, and the guidescope line of sight was vignetted badly by the edge of the aircraft window. The Ames sheet metal shop hurriedly manufactured mounting bracketry to support mirrors to offset the beam to the telescope axis. This "fix" introduced two additional reflecting surfaces, and the brackets were so flexible that the boresight between the two telescopes was impossible to maintain.

Experiment development and preparation- The development chronology below was assembled by an ASSESS observer on a visit to the University of Alaska.

Sept. 1974	Hardware received to date: Interactive Graphic System A010 with hard-copy interface unit Nine track, 45 ips, 10-1/2 in. reel, digital tape recorder with a formatter and minicomputer int Minicomputer and peripheral plus a teletype and paper tape punch/reader
Oct. 21, 1974	Spectrometer arrived from manufacturer, where it had been tested before shipment (monitored 557.7 nm nightglow). Damaged grating will be replaced.
Nov. 6, 1974	Ordered glass filters, also discovered interference in grating drive hitting slit plate; slit plate returned for rework next day
Dec. 4, 1974	Reworked slit plate returned and installed
Dec. 14, 1974	Dark current measurements made versus temperature
Dec. 15, 1974	Suspect PMT cooling problem
Jan. 16, 1975	New grating installed; system optically aligned
Jan. 20, 1975	Performed photometric calibration
Jan. 21, 1975	Weighed components

Feb. 4, 1975 Measured OH in sky brightness; operator problems and apparent noise problem

Feb. 6, 1975 Measured cam sweep angles; suspect grating alignment problems

Feb. 7, 1975 Aligned primary mirror

Feb. 10, 1975 Coinvestigator operates 1-m spectrometer; suspects signal problems

Feb. 11, 1975 Coinvestigator operates spectrometer; finds sticky slit mechanism

Another ASSESS observer visited the home laboratory in late March 1975. By that time the telescope had arrived and was being reconfigured by the in-house electronics engineer to allow focusing on a spectrometer slit instead of the rocket guidance sensor (star tracker). The latter was retained for tracking purposes but was moved off axis as noted earlier. Except for some latent bugs in the computer program, the system was operational. However, the experiment was not operated as a complete system before shipment to Ames in April 1975.

Staffing and support requirements- The two coinvestigators are members of an atmospheric physics research group at the University of Alaska. Technical assistance was provided by two members of a pool generally responsible for aiding several research groups at the university. One technician had the responsibility for getting the spectrometer and data-handling system on line. He also modified the telescope optics, and designed and constructed several peripheral electronic devices (components 8, 9, and 10 in fig. B-33(d) and modified star-tracker electronics). The second technician wrote and debugged the computer program. Both technicians spent considerable time at Ames aiding in experiment installation. Because of their responsibilities in the development of this new experiment, the technicians were quite as knowledgeable as the coinvestigators concerning the operational aspects of the experiment.

INTEGRATION AND CHECKOUT

Payload Integration

One of the key operational features of Spacelab is the concept and approach for experiment-related ground operations, covering the activities from the start of integration to final checkout in the Shuttle Orbiter. Four discrete levels of experiment integration have been defined for Spacelab:

Level IV: Integration and checkout of experiment equipment with individual experiment mounting elements (e.g., racks and pallet segments[4]).

[4]Spacelab flight hardware.

Level III: Combination, integration, and checkout of all experiment mounting elements (e.g., racks, rack sets, and pallet segments[5]) with experiment equipment already installed, and of experiment and Spacelab software.

Level II: Integration and checkout of the combined experiment equipment and experiment mounting elements (e.g., racks, rack sets, and pallet segments[5]) with the flight subsystem support elements (i.e., basic module, igloo, and extension modules when applicable[5]).

Level I: Integration and checkout of the Spacelab and its payload with the Shuttle Orbiter, including the necessary preinstallation testing with simulated interfaces.

These Spacelab integration activities are as independent of each other as possible; they involve different hardware items (flight hardware and GFE) and will take place at different times and different locations. To some extent, the integration of airborne experiments has analogous features, although not as distinctly separable as those listed. The Joint Mission payload integration schedule and activities are briefly described below. Spacelab equivalents are noted where appropriate. The final presimulation milestone was the mission readiness review (MRR) in which payload status and EO readiness were evaluated.

Analogy to Level IV Integration

At home laboratories- At this integration level, a good analogy exists between aircraft and Spacelab. Varying amounts of Level IV type integration were carried out by all Joint Mission PIs in their home laboratories. Most PIs whose experiments occupied rack volume obtained standard racks from ASO for home laboratory integration of electronic components. These racks accept standard 48-cm (19-in.) electronic panels and are mounted as a unit on the aircraft seat rails. Thus, the PI can ensure optimum arrangement and proper cabling of electronic components in the rack before shipping his experiment to Ames. The Meudon/Groningen experimenters built a simple mockup to assist in their home lab integration. They found this procedure desirable to determine the interrelationships of the five racks of equipment and the telescope, and to allow precise precutting of the many connecting cables.

Home lab integration was insufficient in four cases. The Alaska experiment encountered problems in optical alignment at Ames, some of which were never adequately resolved. The Ames dewar did not fit to the Meudon telescope. A primary instrument for JPL was not delivered from the manufacturer until the beginning of the flight period. Finally, the TV camera support for Southampton had to be reinforced to meet aircraft load requirements.

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[5]See footnote 4.

Shipment to Ames-The items shipped to the Ames Research Center for the NASA/ESA Joint Mission fall naturally into two categories, dependent on the home location of the experimenter:

1. Domestic shipment (from U.S.-based experimenters)
   Ames Research Center (Moffett Field, California)
   Jet Propulsion Laboratory (Pasadena, California)
   University of Colorado (Boulder, Colorado)
   University of New Mexico (Albuquerque, New Mexico)
   University of Alaska (Fairbanks, Alaska)

2. Overseas shipment (from European experimenters)
   Southampton University (Southampton, England)
   Queen Mary College (London, England)
   Meudon Observatory (Paris, France)
   Groningen University (Groningen, Holland)

Table B-26 summarizes characteristics of the domestic equipment shipments. Shipping arrangements for the domestic experimental equipment encompassed a wide spectrum of complexity, ranging from the simple case of the Ames Research Center filter-wedge spectrometer, which was simply hand-carried from the PI's lab to the CV-990, to that of the University of Alaska 1-m spectrometer, which was nearly as involved as the overseas shipment. Between these extremes, domestic equipment was shipped by airfreight or transported in vehicles driven from the experimenter's home base to Ames.

In some cases, manufacturers' original packaging was reused for this shipment. There was no overt evidence of damage to items shipped by domestic experimenters. However, in one case, after installation in the CV-990, a plug-in card that had been functional before shipment was found to be defective and had to be replaced.

Table B-27 summarizes the characteristics of the overseas equipment shipment. The overseas shipment was rather complex due to the distance involved and to the requirements imposed by Customs regulations. In general, the overseas experimenters crated their equipment and shipped it to Noordwijk (via Amsterdam), where the crates were opened and the contents examined. The crates were then repacked by ESTEC, and returned to Amsterdam for shipment to Ames Research Center via airfreight. All the items for the Joint Mission were organized into a single shipment for Customs purposes.

The only item that experienced damage was the TV camera of the Southampton experiment: its focusing coil had slipped out of position due to fai[illegible] of the bond on the positioning "C" ring and had partially unwound. This [illegible] had previously been airfreighted to Norway using the same case and packing material. The case consisted of a wooden frame surrounding a heavy corrugated box, which contained several layers of foam rubber and styrofoam.

For this shipment, the case had been trucked 4 miles from Southampton to its airport, flown to Amsterdam, then trucked 20 miles to Noordwijk. It is possible the damage had not been noted there prior to repacking. At any rate,

TABLE B-26.- DOMESTIC SHIPMENT CHARACTERISTICS

Experiment source	Containers shipped	Carrier	Packaging material	Damage	Hand-carried items
Ames Research Center	None	Courier	None	None	All
Jet Propulsion Lab	Separate items	Private vehicle (camper truck)	Foam rubber	None	None
University of Colorado	Separate items	Private vehicle (passenger car)	Foam rubber	Computer plug-in card	None
University of New Mexico	3 wooden crates	Airfreight	Foam rubber and horse-hair padding	None	Timer[a]
University of Alaska	14 boxes	Airfreight	Foam rubber and horse-hair padding	None	Magnetic tape[b]

[a]Carried in pickup camper truck used for transportation from home base to Ames; included also were items overlooked in shipment, all protected with foam rubber.

[b]Also carried was a box of "left-over" items.

TABLE B-27.- OVERSEAS SHIPMENT CHARACTERISTICS

Experiment source	Containers shipped	Route to Noordwijk (ESTEC)[a]	Packaging material	Damage	Hand-carried items
University of Southampton	5 cartons 3 crates	Airfreight/truck	Foam rubber padding, styrofoam blocks	TV camera focusing coil	2 TV camera tubes[b]
Queen Mary College	4 cartons 1 crate	Ferry/truck	Horsehair and foam rubber padding	None	2 thermocouple[c] amplifiers
Meudon Observatory	12 crates	Truck	Plastic bubble wrapped styrofoam blocks	None	Magnetic tape
University of Groningen	3 crates 2 metal cases	Truck	Horsehair and foam rubber padding	None	Backup dewar[d]

[a]Single air freight shipment from ESTEC to Ames.

[b]Necessitated radio contact prior to landing in U.S. to facilitate Customs clearance.

[c]Not included in shipment due to oversight.

[d]Protected by plastic bubble wrap.

it appears that the bond had fatigued due to aging and not due to the crate having been dropped. The TV camera was an obsolete version of a commercial model, which had been modified by the experimenter for image intensification and storage. A positive mechanical bond between the C-ring and the camera frame was subsequently fabricated at ARC after the coil had been rewound and repositioned.

Integration at Ames Laboratory- Some mechanical integration of instruments with special support structures took place at home laboratories. The majority of this work was done at Ames, however, and involved interfaces with aircraft structure. Ames design engineers made a vital contribution to this effort, both by consulting with PIs and by designing the many mounting structures that were fabricated in Ames shops. The most active shop, Metals Fabrication Branch, provided nearly 2700 man-hours of effort to the Joint Mission, including the final integration of standard racks and special supports in the aircraft.

Incoming inspection and assembly- Each experimenter was responsible for examining his equipment at Ames for damage in shipping. (The only serious shipping damage involved the Southampton TV camera tube, as noted in the last section.) After preliminary inspection, components and eventually the completely assembled experiments were given operational checks. Components that were not shipped in the standard racks and those requiring special supports built at Ames were mounted in the flight configuration. Single-phase induction motors used to drive vacuum pumps were modified for spark elimination by replacing the starting switch with a solid-state circuit.

During the lab inspection/check period, the University of Alaska team made the first assembly of their complete optical system in conjunction with Ames personnel. This system comprised a stabilized mirror, 35-cm telescope, and 1-m Ebert-Fastie spectrometer. In addition, provision had to be made for reflecting the beam into the University of Colorado 12.5-cm Ebert spectrometer when desired. This optical system was not in reasonable operating condition until the second checkout flight.

Level I approval- Prior to transfer to the aircraft, each assembly underwent a final inspection for compliance with mechanical specifications, which included the use of aircraft-acceptable hardware, the use of restraints to prevent damage in the event of unexpected accelerations, and the proper placement of equipment so that the overturning and rail-fitting loads and moments were below the allowable maximum.

In effect, these activities amounted to a review and approval of Level IV integration by those responsible for safety. For Spacelab, such functions may well be done before the experiment is shipped from the home laboratory.

Analogies to Integration Levels III, II, and I

Following the inspection and Level IV approval, equipment was loaded aboard the CV-990 for the remainder of the integration process. Because the aircraft is a simpler system than the Spacelab/Orbiter, the remaining levels of integration were not as distinct as those planned for Spacelab and may be considered as a single level combining the features of Spacelab Levels III, II, and I.

Integration schedule- A schedule was prepared to coordinate the flow of onsite integration activities so that all experiments would be in a flight-ready status aboard the aircraft by May 15. This deadline allowed two weeks for inflight verification of payload mechanical integrity, pilot proficiency flights, and the subsequent PI and EO checkout flights. The schedule covered the following activity classes: laboratory assembly and checkout (L), installation on the aircraft (I), electrical hookup in the aircraft to power and signal leads (E), test and alignment in the aircraft (T), and ADDAS interfacing (A).

Table B-28 shows the scheduled and actual sequence of payload integration activities. A comparison of planned and actual events shows that most experiments started out on schedule with work in the ASO laboratory. Mechanical installation in the aircraft started on schedule for the majority of experiments and was generally completed in the allotted time; in the later stages, there were usually several activities going on concurrently. The New Mexico experiment was delayed a week by absence of personnel (prearranged and approved by the Mission Manager), and not all installation activities were completed until after the planned cutoff date.

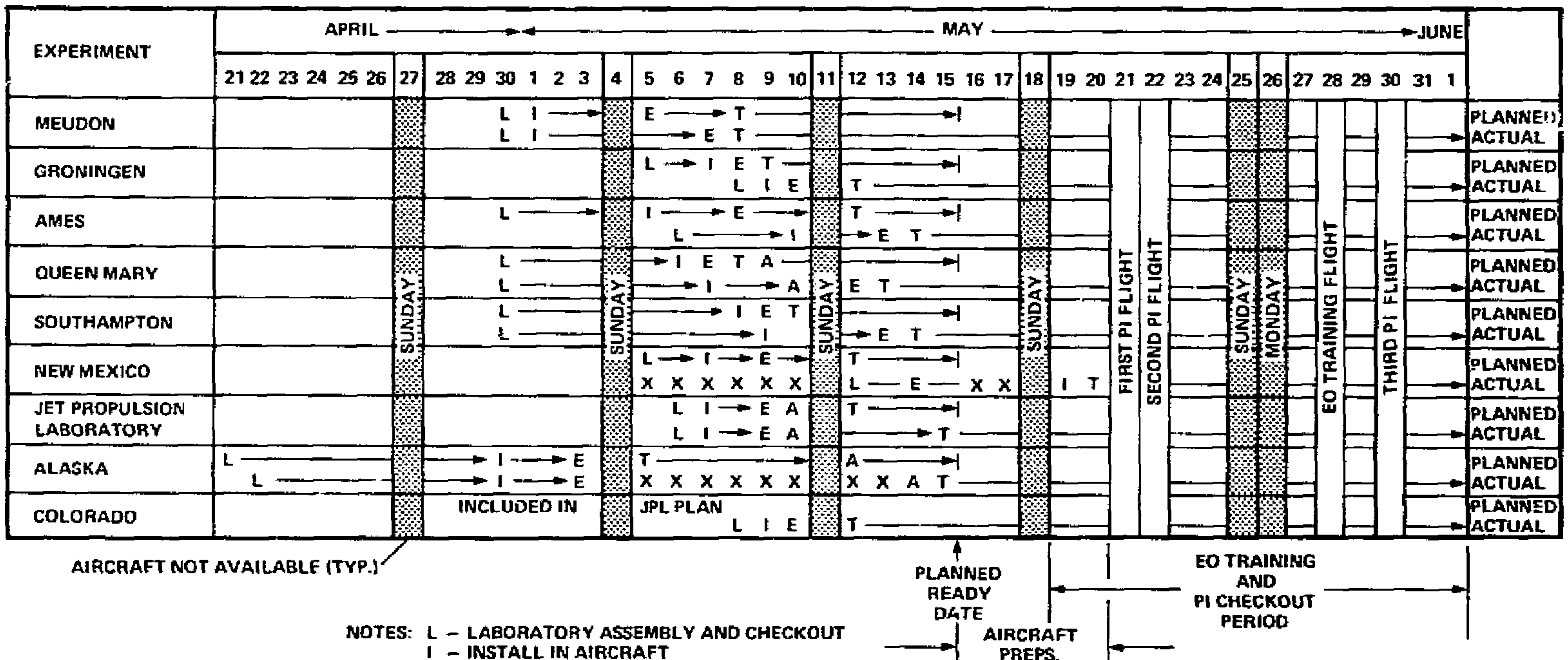
With one exception (New Mexico) noted, the May 15 deadline was met with respect to interfaces with aircraft and experiment support systems, and airworthiness and safety requirements were satisfied. For all experiments, however, much of the next two weeks was spent in further checkout as the principal activity instead of EO training. For this reason, test and alignment is shown as the principal activity in that period.

Activities During Levels III, II, and I

For most experiments, the integration processes aboard the aircraft take the following order:

- Placement and tiedown of equipment racks
- Placement of special mounting fixtures
- Installation of special optical windows
- Installation of other special facilities such as pumps, cryogen supply, and purge-gas supply
- Connection of racks to electrical power
- Connections to and from data system
- Connections to aircraft instrumentation
- Measurement of electrical loads

TABLE B-28.- INTEGRATION SCHEDULE - PLANNED AND ACTUAL



NOTES: L – LABORATORY ASSEMBLY AND CHECKOUT
I – INSTALL IN AIRCRAFT
E – ELECTRICAL AND SIGNAL CONNECTIONS
T – TEST AND ALIGNMENT IN AIRCRAFT
A – ADDAS INTERFACE
X – NO PERSONNEL PRESENT

Checkout of equipment
Final inspection — mechanical, electrical, safety (add padding if needed to prevent personal injury)
Installation of black shrouding curtains around light sensitive equipment

The mechanical and electrical integration into the aircraft took a total of two weeks. The Airworthiness and Flight Safety Review Board then met to determine that the aircraft and its payload were physically ready to fly. No major problems were found during this review, and the board gave its written consent for the mission to proceed.

When payload integration was complete, each experiment and the entire installation was carefully checked out on the ground. A total of 20 hr was devoted to this activity. As experiments were turned on, others were checked for possible electrical interference. Signals to the ADDAS were double checked before the actual connection was made to avoid electrical damage to the computing system. The aircraft was positioned in as dark an area as possible to permit astronomical observations, and the instrumentation was operated to the extent permitted at ground level. In this way, it was possible to determine whether experiments making astronomical observations were operating properly, although signal strengths in both the UV and the IR were far below those expected at altitude. For skyglow experiments, it was possible to check sensitivities, although not in the exact wavebands desired at altitude. Full checks were made of cryogenic cooling.

Mission Readiness Review

The status of the experiments and EO training was assessed during an informal MRR on May 29, following the last scheduled flight of the presimulation period. The review was chaired by the Mission Manager, and attended by the PIs, EOs, ASO participants, and MPG representatives. It was soon apparent that payload preparations for the simulation mission had not been completed. Only one or two experiments were in a ready status. In each case, however, the outstanding problems had been identified and were on the way to solution. Several changes in the handling of ground support equipment were requested to facilitate EO activities during the confined period. Because of the emphasis on hardware problems, EO training had not progressed to ready status.

It was agreed that final preparations could be completed in time for the scheduled start of the simulation period. To this end, requests were made for a fourth premission flight for experiment checkout, and for ground support personnel as necessary to operate experiments for EO training through the weekend. Both requests were changes to the mission plan, justified by the immediate circumstances and subsequently implemented. A second operator training flight was also requested. It was not approved, however, as the MPG representatives judged it to be a serious breach of mission guidelines. In a sense, the MRR experience was a capsule summary of mission preparations for the previous year, and brought to focus a number of important points:

1. Experiment development delayed beyond the ERR date will adversely impact EO training and final integration activities.

2. Mission planning should allow a contingency period for unexpected problems during integration and simulator testing.

3. Individual experiments that make up a composite payload, if allowed to develop separately, may not achieve the desired result when integrated, and some compromise of research objectives may result.

4. When EOs are to perform time-shared, multiple experiment functions, the authority of the Mission Manager should be adequate to assure compliance with milestone schedules for experiment development and operator training.

5. Experiment development must be monitored effectively so that delays can be recognized promptly and early responses facilitated where scheduling is flexible, and to minimize impacts on other experiments and support functions.

6. Early transition from passive to active hands-on training is important. Only by this means can an operator develop the skills that allow concentration on results rather than procedures.

EXPERIMENT OPERATION AND PERFORMANCE

Two major design criteria governed the original development of the ASO CV-990 standard equipment rack: (1) the aircraft was designed to carry passengers, so the seat rails were the obvious tie-down points for the racks; and (2) the seat rails were designed to handle two seated people per unit length on the left side, and three on the right. The first factor influenced the orientation of the racks in the cabin, and the second, how the rack could be loaded (total) weight, overturning moment, etc.). The rack that evolved is not necessarily the most convenient for mounting large, complex, or grouped experiments, nor can components mounted in the rack always be placed at levels that ease experiment operation. No attempt was made during the NASA/ESA mission to develop centralized control panels for EO operation, so both equipment rack orientation and component placement figure prominently in the following discussion on experiment operation.

Control Stations

The CV-990 floor plan of figure B-1 is enlarged in three sections (figs. B-34, B-35, and B-36) to show the working spaces of the three EOs. As the EO operated the experiments, he moved among the standard equipment racks and other major components to adjust the principal controls and monitor readouts. Arrowheads just touching the rack indicate controls on components mounted in the rack, while arrows crossing the rack outline indicate controls on components mounted on top of the racks.

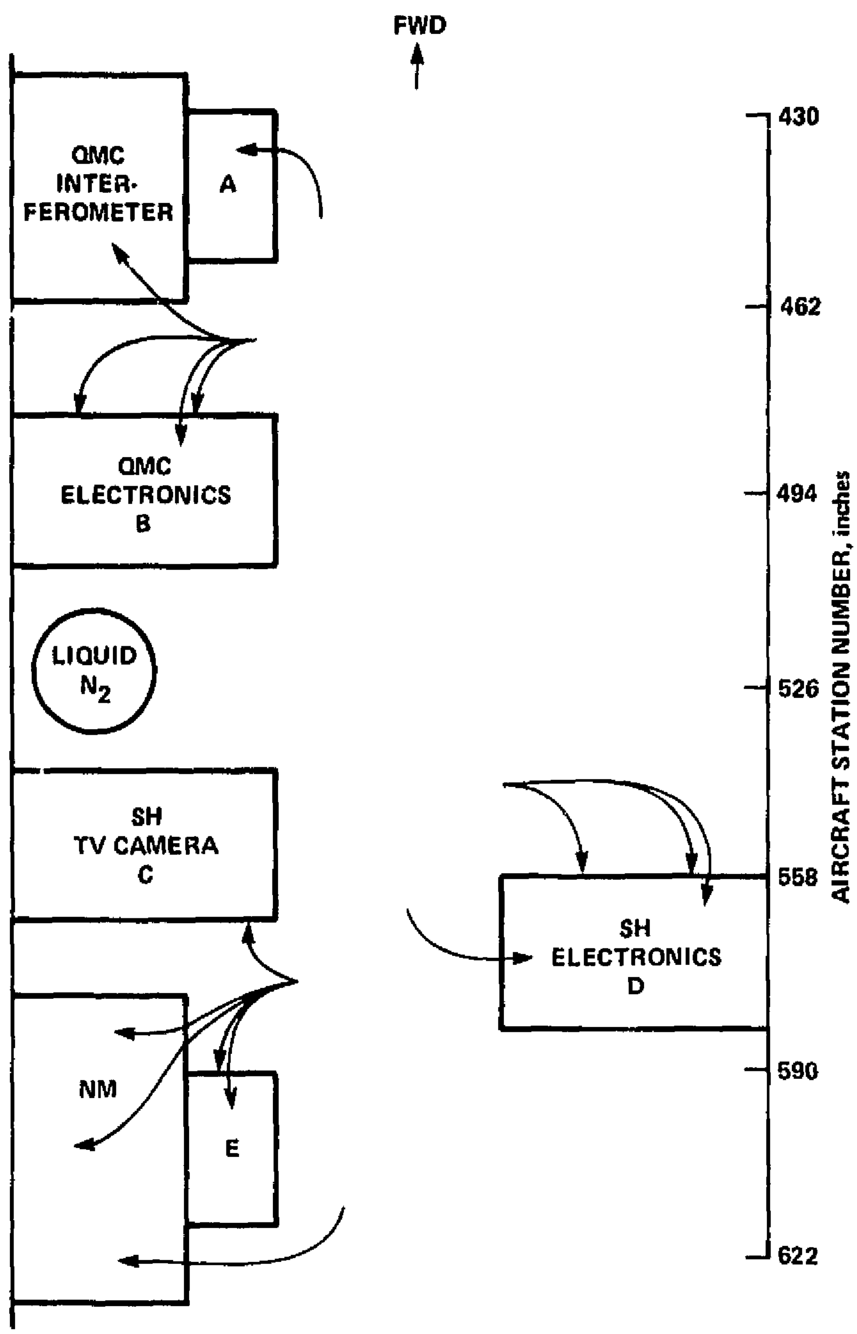


Figure B-34.- QMC/SH/NM station.

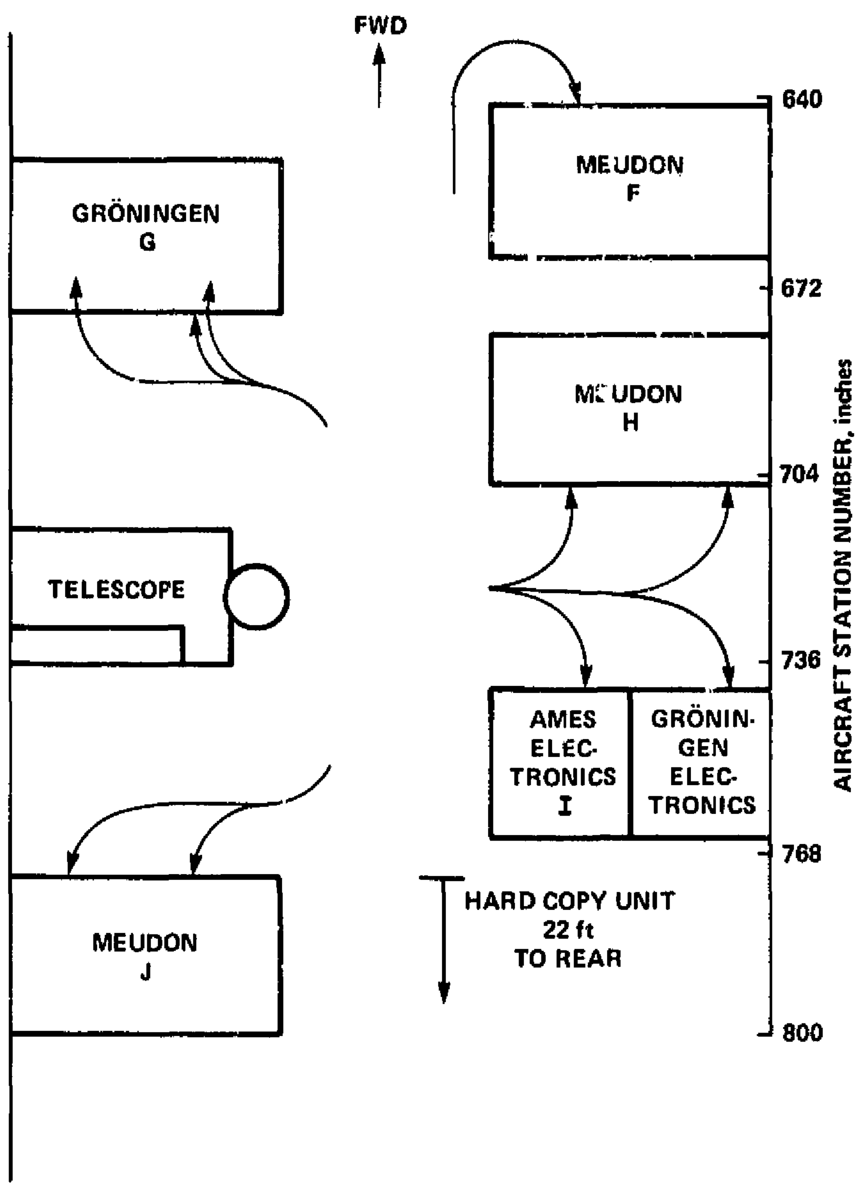


Figure B-35.- Meudon/Groningen/Ames station.

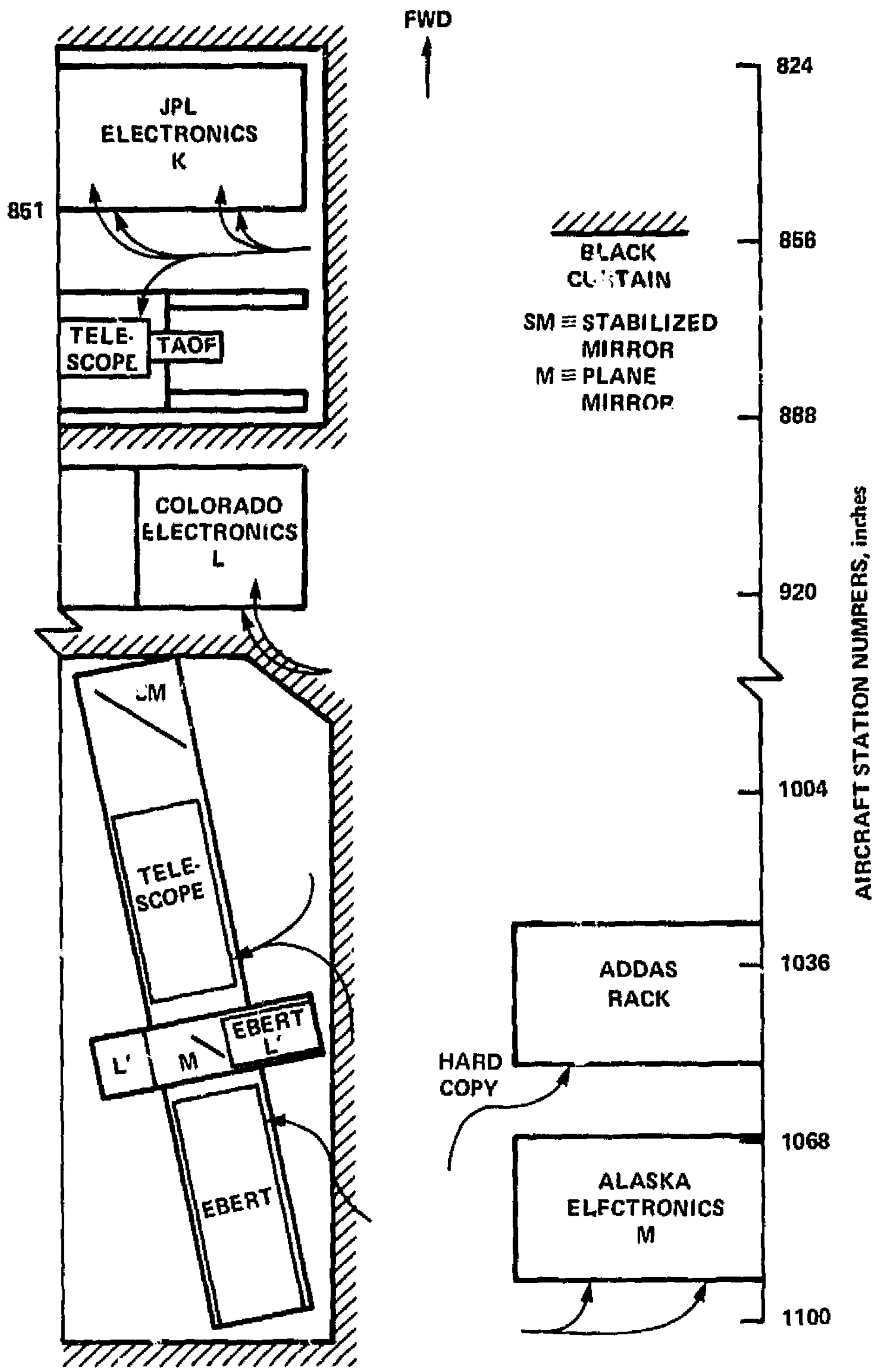


Figure B-36.- JPL/Colorado/Alaska station.

The general ASO installation philosophy is to place a seat-pair behind each rack of equipment. In the general case the experiment operator remains at one equipment rack, and the seats allow operation from a comfortable position with even floor-level controls in relatively easy access. For the Joint Mission, however, the EOs had to move quite frequently from one rack to another to carry out their assignments, and although the equipment racks and other components were grouped as logically as possible, none of the stations were particularly convenient for experiment operation.

Because it included only a single sensing device, the Meudon/Groningen/ARC experiment group (fig. B-35) was the most amenable of the three to centralized control. Nevertheless, the operator had to go forward to rack F to load his computer program, across the aisle to rack J to power-up telescope stabilization and scanning components, and across the aisle and forward to rack G to start tape recorders and change tapes as required. He otherwise spent most of his time between racks H and I. However, because of the location of components in these racks, the EO had to work while on his knees or sitting on the floor — not a position most adults can endure for very long. Six channels of housekeeping information were displayed in rack F, but if the experiment was operating normally this information was seldom monitored. The EO was requested to make hard copy of his computer terminal displays (IR maps of the observed targets). This could be accomplished at the computer terminal, but he had to walk 20 ft to the rear to collect the actual copy. He did this seldom during flight, preferring to leave them at the hard-copy unit and collect them after the flight.

The other two EO stations (figs. B-34 and B-36) had three or more primary control centers distributed over 18 to 20 ft along both sides of the aisle. Depending on the degree of automation, some experiments required more EO attention than others, but all had to be visited fairly frequently during flight. The QMC/SH/NM EO generally turned on QMC first (racks A and B), and then SH (racks C and D) and NM (rack E) as sky brightness conditions allowed. Southampton had a 180° FOV zenith pointing camera mounted on axis just aft of rack B, a TV camera mounted on top of rack C that pointed at 25° from zenith, and a photometer at the same angle in a window just forward of rack E; but these normally required no hands-on activity to turn on or operate. After completing turn on, the EO spent most of his time at the QMC station (because of lack of automation) with frequent monitoring of the operation at the other racks in his control. The liquid nitrogen storage (between racks B and C in fig. B-34) supplied coolant for a 77 K reference black body in the QMC interferometer. The transfer controls were on top of the storage dewar, but the PI decided to simplify the operation during the simulation period by not cooling this reference body. Thus, the EO had no occasion to activate the transfer controls on the storage dewar. Frequently adjusted controls at the QMC station could be reached with the EO standing or slightly bent over.

The JPL/Colorado/Alaska station (fig. B-36) was the most difficult to handle. The controls were distributed over a greater distance along the aisle, and even though the aircraft cabin was quite dark, two portions of the station were surrounded by black cloth to reduce the amount of radiation scattered into the open optical paths. The NM and SH experiments were also very

sensitive to scattered cabin light, but in both cases only the critical sections of the optical path were shielded so that the EO only occasionally needed a flashlight (red filtered) during experiment operation. Activities at JPL (rack K) or around the Colorado/Alaska telescope were carried out with the EO holding a flashlight in one hand, a disadvantage on occasion.

The JPL/Alaska/Colorado EO turned on the Colorado (rack L) or Alaska (rack N) first, depending on which was first to receive the signal from the 35-cm telescope. JPL (rack K) was generally the last to be brought to its full operational state. After each experiment was fully operational, the EO spent approximately equal amounts of time at racks K, L, and N and inside the rear curtained enclosure.

Racks L and N were the only two in the aircraft with seats immediately to their rear from which the EO could operate the installed components. Rack-top mounting on rack L, however, made standing more convenient there.

The ASO hard-copy unit (part of ADDAS) mounted in rack P (fig. B-36) was used by the Meudon/Groningen and Alaska experiments. It produced copy of their computer terminal displays, maps in the form of numerical arrays for the former and average spectra for the latter. Since the copier was convenient to his station, the Alaska EO generally collected his copies immediately.

Basic Indicators of Proper Operation

For meaningful control of a scientific experiment, an operator must be provided with indicators that display or record the vital signs that enable him to monitor performance, judge the quality of results being obtained, and take corrective action when trouble occurs. It was the responsibility of the PIs in the Joint Mission to decide which experiment functions should be automated and would not require operator attention, which functions needed to be monitored and the appropriate type of indicators, and which would be operator tasks requiring judgment and action in response to indicator signals.

Table B-29 lists the experiment performance indicators provided for the Joint Mission. Some were new to the experiments for this mission, but so far as could be determined, none were incorporated for the purpose of making it easier for the EOs to determine if operations were proceeding satisfactorily. Rather, their purpose was simply to permit the EOs to monitor experiment operation. Few proved unnecessary; in several instances, additional indicators would have been helpful. Meters were generally standard electrical indicators or digital readouts (both electrical and mechanical). This class of indicators included 22 units. Fourteen examples of photocathode displays were observed. Writing devices were stripchart or X-Y recorders with a total of 17 channels. There were nine other visible or audible indicators of performance. Principal features of the various indicator systems are discussed below, by experiment.

Queen Mary College- Detector sensitivity was a strong function of detector temperature, and adequate sensitivity could not be achieved unless detector temperature was at or below 2.5 K. Detector temperature was maintained below

TABLE B-29.- PRINCIPAL EXPERIMENT PERFORMANCE INDICATORS

Experiment	Meters		Photocathode displays			Writing devices	Other
	Dedicated	Random connection	Oscilloscopes		Other		
			Dedicated	Random connection			
QMC							
Signal channel	a.c. amplifier output Lock-in detector output		Dual beam; amplified a.c. signal			Stripchart; demodulated signal	
House-keeping	Helium bath pressure	Digital; volts and resistance	Reference voltage				Mirror position indicator
SH							
Signal channel	Lock-in detector output (photometer)			Video or photometer signal	TV; star field display	Stripchart; demodulated photometer signal	
House-keeping							Tape movement
New Mexico							
Signal channel					Image-intensifier photo-cathode display through camera view-finder (2)	Dual-channel stripchart; (channel 1) photometer signal	

TABLE B-29.- Continued

Experiment	Meters		Photocathode displays			Writing devices	Other
	Dedicated	Random connection	Oscilloscopes: Dedicated	Oscilloscopes: Random connection	Other		
NM (contd.)							
House-keeping	35-mm camera frame counter, 16-mm camera film footage counter					(channel 2) 35-mm camera fire pulse	Audible came[illegible] shutter sounds
Meudon/ Groningen							
Signal channel	Lock-in detector output				Terminal display	Stripchart (provided by Ames expt.); demodulated signal	
House-keeping	Vertical and horizontal servo error currents Helium bath pressure			Control voltages	TV; star field and area of automatic guide	Six-channel stripchart; control voltages	Tape movement (2)
Colorado							
Signal channel	Digital; photon count				Terminal display; summed spectra	Stripchart; data replay from mag-netic tape	Audible grating motion sounds
House-keeping							Tape movement

TABLE B-29.- Concluded

Experiment	Meters		Photocathode displays			Writing devices	Other
	Dedicated	Random connection	Oscilloscopes: Dedicated	Oscilloscopes: Random connection	Other		
Ames							
Signal channel	Lock-in detector output		Modulated signal			Dual-channel stripchart; (channel 1) signal	
House-keeping		Digital; volts and resistance				(channel 2) filter position	
JPL							
Signal channel	Digital; photon count (UV TAOF)					X-Y plotter (one signal channel)	
House-keeping	Digital; RF frequency meters (2) Output of high voltage power supply (visual TAOF PMT)		Sweep voltage (visual or UV)				
Alaska							
Signal channel					Terminal display; summed spectra	Dual channel stripchart; pre- and post-multiplex signal	Grating drive cam motion
House-keeping	Output of PMT power supply	Usually output of star tracker					
Total number of indicators	17	5	5	2	7	17	9

4.2 K by controlling the pressure above the liquid helium bath that supplies primary cooling. Thus, the operator had to be sure that helium bath pressure had stabilized below some upper limit if he was to collect high-quality data. Having achieved this situation, the operator paid most attention to the oscilloscope and the stripchart recorder. The former showed alternately on one channel the signal from the atmosphere and the signal from the reference black body (several cycles fit across the screen) and on the other channel the reference voltage that went to the lock-in amplifier. The output of the lock-in amplifier (the difference between the atmospheric and the black body signals) went into the stripchart. The sporadic noise bursts later identified as EMI were clearly evident on both the oscilloscope and the stripchart. This easy visibility allowed correlation of the noise with the use of aircraft communications equipment.

Southampton- The TV system was monitored primarily by observing the end product — the TV picture. The video signal could be checked on the oscilloscope, but this usually displayed the modulated (chopped) photometer signal. Since the stripchart recorder made the sole record of the photometer signal it was frequently annotated with experiment parameters, but the oscilloscope display was the principal indicator of proper photometer operation. There was no easy way to monitor operation of the 180° FOV camera. The noise made by the shutter mechanism indicated that at least the camera was being actuated. In this case, however, the camera was at a zenith window and not readily accessible, and the exposures were of 16-min duration, so listening for camera noise was impractical, especially for an EO with many other duties.

New Mexico- In contrast to the Southampton camera, the 35-mm and 16-mm cameras fired once a minute and once a second, respectively, and were near the aisle where they could be easily heard. Also, they both had indicators of film usage. Operation of the image intensifiers could be monitored by looking at the image screen through the camera viewfinders. The stripchart record monitored both the photometer and the filter-wheel operation (20-sec steps in signal level with one "dark current" step). The marker pen channel on the stripchart recorded application of voltage to the 35-mm camera's shutter, but it was meant for correlation of the two records, not for monitoring camera operation.

Meudon/Groningen- As with QMC, the detector sensitivity was a strong function of detector temperature so the operator would get data of very low quality unless the helium bath pressure was stabilized at or below some upper limit. Having achieved operating pressure, he monitored the quality of the data channel signal at the lock-in detector (inconveniently located and infrequently referred to), on a stripchart recorder (time-shared with Ames), and on the integrated hard-copy maps printed out by the minicomputer. The integrated map provided the best estimate, especially when a known astronomical target was being observed. However, the stripchart was adequate, and diagnostic activities related to signal quality usually started from hints of trouble observed on that record.

Telescope pointing and tracking could be monitored on the TV, which displayed the guidescope star field and the area of the field in which the

telescope electronics could automatically track; if the guide star remained centered in this area, tracking was satisfactory. Early in the mission, tracking control was marginal. Two meters were installed to ascertain whether the servo loops were actually sending signals to correct tracking errors. These meters did indicate the presence of error signals, and thus served their purpose, but were left in the system as another monitor of servo-loop operation. The operation of the raster scan of the main telescope relative to the pointing direction of the guidescope could not be monitored directly; the drive-voltage waveforms could be monitored on the six-channel stripchart, but in real time their actual effect on telescope orientation had to be assumed.

Colorado- This experiment was designed for totally remote operation but included no special indicators of improper operation. The spectra were summed in real time (as distinct from simply printing out the result) and the accruing sum of one data channel or the other displayed at the interactive terminal. After several spectra had been summed, the operator could assess data quality and could observe information being added (point by point) to the sum. However, the latter aspect of the display was not a straightforward indication that all was well. For example, if 50 or so spectra had been summed (sufficient for spectral details to be visible) and then a failure caused the grating motion to stop, which happened several times, the displayed spectrum would maintain a spectral shape and continue to increase in amplitude, but by a constant amount in each data-processor channel. After it had happened once, the EOs stopped near the spectrometer occasionally to listen for sounds of grating motion. The display could not be switched from one data channel to the other during the computer-controlled sequence of spectral sweeps. The photon-counting meter was also dedicated to the same channel displayed at the terminal during a given recording sequence, so the operator could monitor the operation of only one of the data channels at any given time.

Ames- The Ames detector was cooled only to 77 K with liquid nitrogen at cabin pressure, so there was no cryogenic bath pressure criterion for successful operation of the experiment as in the Meudon/Groningen case. Telescope operation was also simpler in that only the automatic tracking capability was used; it was not raster-scanned. Thus, the computer and its terminal display were omitted from the system. The operator still had the modulated signal on an oscilloscope and the demodulated signal (lock-in output and stripchart) as references for proper operation. He utilized the stripchart record primarily, and the Meudon TV for telescope tracking.

JPL- This experiment included what seemed to be adequate performance monitoring instrumentation, but (apparently) sensitivity was so low that the EOs and PI were never sure they were recording usable spectral data. It took a light source several orders of magnitude brighter than the night sky (the usual target) to produce recognizable spectral features on the X-Y plotter.

Alaska- The meter used in connection with the star tracker was for the purpose of initially determining when the main telescope was on an astronomical target (centering the target in the guide telescope never put the main scope on target; the initial boresight was always faulty). The meter leads were clipped to the output of the star tracker until the target was acquired,

then the meter was disconnected and stowed. The guidescope was then adjusted to center the target and allow the operator to more readily check performance of the tracking system. Overall experiment operation was monitored primarily at the terminal display. In contrast to the Colorado experiment in which spectra were added to the display in real time, in the Alaska system the operator had to command a memory dump to cause the sum of the collected spectra to be displayed. Individual spectra could be read out on the stripchart recorder, although amplitudes were not necessarily high enough to allow an assessment of data quality. The principal purpose of the stripchart display was to compare the pre- and postmultiplex signals for accuracy of the operation. This experiment was the only one that included a real-time monitor of data-processing accuracy. Other PIs relied on playing back selected sections of data from their tapes — the ultimate check on the accuracy of their data systems.

Operating Procedures and Problems

Detailed operational procedures for each experiment as developed by the PIs and EOs are given in Appendix A, *The Experiment Operator* (ref. 3). This section describes what happened during the Joint Mission when the EOs and PIs operated the experiments. Tables B-32 and B-33 (at the end of the section) list all operational problems encountered by the EOs and PIs, respectively, and indicate the impact of those problems.

It should be noted that most PIs give little attention to easy access to internal parts for the purposes of troubleshooting problems and repair. Certain critical voltages were perhaps constantly metered or brought to test points on a front panel, but seldom were components mounted in racks on drawer slides, for example, which would allow immediate access to internal test points or parts (if replacement was indicated by panel test-point measurements). For normal operation, this philosophy is understandable: the PI does not have a timeline cluttered with maintaining and operating other experiments in addition to his own. If he devotes an hour to diagnosing a problem, he is the sole loser. In addition, such refinements as drawer slides would add to his costs. For the multiple-experiment operation required of the EOs on the Joint Mission, however, such economies and independence of experiment design proved detrimental in many cases.

Simulation Flights

Queen Mary College- The main operational problem experienced by QMC was EMI from the aircraft's VHF transmitter, primarily in the 133-MHz region of this band. The VHF antenna was mounted in a zenith position about one meter forward of the QMC experiment; thus, interference from the transmitter was not surprising. The sensitive point in the circuitry was presumably at or near the detector. At any rate, electromagnetic shielding placed around this component during the PI flights reduced the interference but never eliminated it. The same type of detector was used successfully by Groningen during the Joint Mission, and had also been used with no EMI problems by several PIs on the

ASO Lear Jet. Apparently, some combination of circuit design characteristics peculiar to QMC and proximity to the VHF antenna led to the EMI problem.

Two other less serious problems persisted throughout the simulation period. One was related to lack of automation in interferometer operation and the tight EO timeline. The EO frequently misjudged or forgot the position of the moving interferometer mirror, which jammed on reaching the end of its travel. To release it, the EO had to remove a portion of the interferometer cover (several bolts were involved), reverse the drive, and simultaneously wiggle the mirror. The complete operation took several minutes. The second problem also required removing a (different) portion of the interferometer cover. With the vibration of takeoff, the light pipe that coupled the dewar/detector to the interferometer worked loose and slid forward. After each takeoff the EO had to remove the lid and reseat the pipe element. This too was a several-minute operation, but fortunately it could be performed during a period of relatively light EO workload.

Southampton- The Southampton experiment performed well during the ASSESS mission. The only problem requiring repeated EO attention concerned a multiple-pin connector in the TV camera, which jiggled loose with the vibration of each takeoff. To reseat the connector, the EO had to remove the cover plate from the lower end of the camera, exposing high-voltage electronic components, reseat the connector, and replace the cover plate. The whole operation took ten or more minutes, and occurred during the busy period when all experiments were being put into operation.

New Mexico- The New Mexico experiment demonstrated the importance of checkout flights (or their equivalent). Several serious problems arose during these flights, and judging by later performance, were all successfully resolved. Only two stripchart problems and weak batteries in the 35-mm camera drive required EO attention during the simulation mission. The malfunctioning stripchart remained unrepaired at the end of the confined period because of the lack of a small enough allen wrench in the tool kit.

Under ordinary operating conditions, the New Mexico PI had the option of moving components 1, 2, and 3 (fig. B-12), including the filter-wheel and support structure, directly across the aisle to an alternate, prewired station if viewing conditions on the right seemed better to him than those on the left. When performed by two people, the operation required 10 to 15 minutes to complete. To reduce the EOs' workload, this option was dropped from experiment operation during the simulation period. The only change in experiment configuration expected of the EO was to mount and demount the 16-mm camera (5) as required for stowing during takeoff and landing. This operation took only two or three minutes, and occurred during low-priority time periods.

Meudon/Groningen- Aside from an adverse reaction to the CV-990 environment, the Meudon/Groningen experiment worked very well. The fuses that blew near the end of flight 6 were performing a proper function -- that is, protecting against transients in the aircraft power system. There were no internal failures during the simulation mission. The photometer lacked sensitivity

during the whole of flight 7, but this is thought to have been caused by a poor helium transfer on the part of the EO. The exact reason was not definitely established.

Ames- The Meudon telescope continued to work well during the last two flights when the Ames experiment was coupled to it, but performance of the latter was poor primarily because the detector was both vibration-sensitive and susceptible to EMI from aircraft systems. The EO continued the PI's diagnostic efforts on both of his off-duty nights prior to the mating of the Ames experiment to the telescope, but made no significant progress in lowering signal channel noise. The noise degraded all data and caused some loss on the weaker IR targets; that is, since the signal-to-noise ratio was apparently less than one, the EO eschewed or made only token attempts at guiding. The remainder of the experiment performed satisfactorily. There were no component failures.

JPL- The EOs were able to obtain little or no spectral information through the system, and one EO remarked that he could never tell if it was operating correctly or not. The reason for this low level of performance was not clear. The visible TAOF apparently operated satisfactorily during the home lab EO training sessions, although much less well at the field station tests. The UV TAOF system, while the same in principle, was actually improved over the visible system in one respect. As noted earlier, the PMT high-voltage power supply in the UV system was contained in the PMT housing itself, instead of being rack mounted and separated from the PMT by many feet of cable. (The visible TAOF, when operated by the PI, suffered from a very high background signal traceable to this component separation.) Of course, late delivery of the UV TAOF precluded proper laboratory check-out. The lack of sensitivity may possibly have resulted from a defect in the filter element itself. The problem was not diagnosed during the mission.

In addition to the possible sensitivity problem, the experiment was susceptible to EMI by aircraft systems. The EMI measurements carried out by ESTEC after the simulation flights showed that all CV-990 experimenters' power cables carried a wide variety of stray rf components (the measurements revealed frequencies from ~10 kHz on up to ~500 MHz, the cutoff frequency of the diagnostic equipment). The frequencies required to tune the TAOF are in the 100-MHz range. When the TAOF drive frequency was in the region of 120 to 130 MHz, stray rf components somehow got into the signal channel and produced spurious spectral features in the output. The EOs, both primary and secondary, made many changes in grounding points and in cable distribution, but did not succeed in eliminating the EMI. All spectra obtained, such as they were, required correction for this interference.

Colorado- In spite of its sophistication, the Colorado experiment gave the EOs many operational problems. The spectrometer control/display (3) was not working quite correctly when the simulation mission began. The EOs were able to accomplish the routine tasks requested by the coinvestigator, but not certain operations concerning real-time data analysis known to be within system capability (such as expand spectrum baselines and read wavelengths of spectral features). During the second simulation flight the display feature

malfunctioned, leaving the EO with no quick-look information on proper experiment operation. After almost two full days of intermittent diagnostic effort (the period during which the aircraft was grounded for an engine change), the EOs found a blown fuse internal to component 3 (fig. B-31) that even the coinvestigator didn't know existed. Replacing the fuse brought the unit back to proper operation as far as the EOs were concerned. The PI found a loose PC board after the simulation mission. Reseating the board returned full operational capabilities.

Most other operational problems were related to computer program hangups — for example, the program would not write on tape or would not transfer data from tape to stripchart. Usually the EO was able to restart successfully in a few minutes, but during the first simulation flight all data were lost because the EO could not get the system up via the computer terminal. The frequent computer hangups (six occurred during the five simulation flights) may have been caused by EO inexperience; none was observed during the six flights made subsequently by the coinvestigator.

Another problem, which could not be corrected aboard the aircraft, was occasional stalling of the spectrometer grating drive. To properly diagnose the cause would have required disassembling the spectrometer with special tools in a clean room (in the technical sense), a task of which only the coinvestigator (primarily an instrument design and construction expert) was capable. Fortunately, the EOs found that the grating could be restarted by the simple expedient of turning grating drive power off and then on again. This worked on two different flights, but data were lost because the EO had no way of knowing the grating was moving properly except by the sound it made. In the high ambient noise level of the aircraft, he had to place his ear near the spectrometer, which among his other duties, he could do only infrequently. The grating drive apparently cleared itself before the end of the simulation mission.

Alaska- The Alaska/Colorado/JPL EO was asked to switch the telescope beam from the Alaska to the Colorado spectrometer slit (or vice versa) at least once during each flight, usually while guiding on Venus. This was done in one or two minutes by positioning (or removing) a mirror in front of the Colorado spectrometer with an orientation of 45° to the optical axis of the telescope (M in fig. B-33(a)). This arrangement was not appropriate for the data-taking capabilities of the Colorado instrument, because without further focusing, the image, while matching the Alaska input slit, was tens of times too large for the Colorado slit. The arrangement was worked out between the JPL and Alaska investigators without any known consultation with the Colorado investigator, who was well versed in optical technique and would undoubtedly have objected. As it was, he was forced to accept the situation until after the simulation period when he moved his instrument to one of the JPL 20-cm Schmidt telescopes. The improved optical match and the generally superior optical quality of the JPL telescope improved the Colorado signal by more than two orders of magnitude.

The most difficult aspect of operating the Alaska/Colorado optics (during the simulation period) was astronomical target acquisition in fairly bright

sky. The EOs spent only 50 percent of available time on the flight's first target, with the percentage being much lower than that early in the simulation period (Appendix A, ref. 3). This occurred because the telescope system would not maintain boresight.

Other than the frequent loss of boresight, the Alaska experiment performed well except on one occasion when the computer could not write on the stripchart recorder, and on another when the computer would not accept calibration lamp data from the spectrometer. Both problems occurred at the very end of the flights, thus causing no loss of data. In the first instance, the PI had unintentionally disconnected power to the D/A converter that provided the stripchart signal when he removed the malfunctioning magnetic tape recorder from the experiment (after flight 4). At the end of flight 6 (second simulation flight) the EO again encountered the problem while attempting to generate some hard copy for investigator perusal. The problem was diagnosed in consultation with the investigator, and the EO merely had to reconnect the power leads. The computer's refusal to accept spectrometer data (end of flight 8) was due to an open circuit breaker, which was apparently opened by a power line surge. The open breaker was discovered during the day following the flight, and resetting the breaker resolved the problem.

PI Data Fligh

This subsection covers operation of the experiments by the PIs during the checkout flights preceding the simulation period, PI aspects of experiment operation during flight 3 (the EO training flight), and the PI experiment operation during the data flights following the simulation period.

Queen Mary College- The senior PI of this experiment was aboard and participated actively in experiment operation only during flights 1 and 2. The experiment operation was otherwise left to a junior coinvestigator and a senior technician. The nature of the experiment easily allowed this arrangement, for few decisions requiring scientific expertise were required in flight.

The experiment encountered two persistent problems: a d.c. offset signal reflected by the chopper, and EMI. The first was recognized early and could be eliminated by slight repositioning of the chopper wheel, which was done frequently in flight. The second was actually analyzed correctly by the EOs during the constrained week. The EMI was reduced but never eliminated during the mission. Aircraft radio communications ruined a fairly high percentage of attempted interferograms.

Most problems that occurred in flight were resolved on the ground following the flight. A problem on flight 1 involving a stripchart recorder was resolved by borrowing a recorder from Ames for use during the remainder of the mission.

This experiment was basically ready to be operated by an EO by the date of the EO training flight (3). Operation for the constrained period was simplified somewhat by omitting reference to the 77 K black body.

The requirement for real-time ADDAS computations to give Fourier transforms of QMC interferograms was important only during the contrained period and was largely ignored during the PI data flights.

Southampton- The PI for this experiment was aboard the CV-990 only during three flights (2, 14, and 15) and played a passive role in experiment operation, leaving actual operation to others. During other flights, the experiment was operated by one or two graduate students from the PI's laboratory. Low PI profile was acceptable because after initial turn-on, the experiment required little attention from the operator and no scientific value judgments.

Only one problem persisted throughout the mission: a multiple pin connector in the rear of the TV camera generally shook loose on takeoff and had to be reseated by the operator after removing a cover panel. The problem was analyzed during the first flight by the senior graduate student of the Southampton group.

Only two other problems occurred during the nonconstrained portion of the mission, both on flight 10. These were resolved on the ground by the graduate students.

New Mexico- Both PIs accompanied this experiment on the PI data flights, but only one PI was present on flights 3 (EO training) and 4. In flight, scientific value judgments were required (whether to use the left or right-side viewing stations) so the presence of a PI was of some importance. The PI was twice requested to solve small problems during the EO training flight (3). The New Mexico PIs correlated observations of OH with others making similar observations (Alaska and Southampton during flight 14). (OH concentration and structure of OH clouds was the only major common scientific interest among the NASA/ESA PIs.)

This experiment is simple in concept and operation, and it was in proper operational condition at the start of the mission. The only major problem occurred on the first flight. The 35-mm camera film transport malfunctioned in a way that could not be readily repaired, and a replacement unit was borrowed from Ames. The Ames camera required redesign of the mount. Other minor problems were resolved in flight except for a stripchart malfunction late in the mission. In this case, a backup unit was put into service.

Meudon/Groningen- This experiment involved PIs from two different institutions — one from Meudon who supplied the basic telescope and associated electronics, and one from Groningen who supplied the complementary components (dewar/dectector, etc.) required for IR astronomy. Both PIs had several capable assistants who carried out the installation and check flight phases of the mission (including the EO flight in the Meudon case). Both PIs were aboard flights 4, 10 through 14, and 15. Their principal contribution, however, was in flight planning rather than actual experiment operation. All but two flight paths were constructed primarily to meet Meudon/Groningen requirements. Other PIs took targets of opportunity or were not so dependent on exact flight path. No other experiments were directly concerned with the IR targets chosen by Meudon/Groningen.

This experiment encountered two persistent problems, both related to the telescope interface with the aircraft flight environment. The more serious of the two was aerodynamic buffeting of the telescope in its cavity. The initial solution was to install a mylar sheet over the telescope cavity, which eliminated the buffeting but caused large attenuations of the IR signal. A new aerodynamic spoiler, designed by Ames engineers, was constructed and used successfully on the last flight of the mission. The second problem related to inability of the aircraft autopilot to control the roll within acceptable limits for the telescope elevation control. The autopilot instability required extra effort by the pilots to minimize roll; gradually they improved roll control to the satisfaction of the experimenter.

The EO training flight took place before any solution to the buffeting problem had been attempted. Operation was further impaired by poor telescope balance. The combination, buffeting and imbalance, severely taxed the telescope torque motors. A Meudon technician worked on telescope balance throughout the flight. Partial success in telescope guidance was finally attained by a Meudon coinvestigator (not the EO) near the end of the flight.

Aside from the problems arising from telescope buffeting, the complete system gave almost trouble-free operation throughout the mission. The Groningen PI was asked to resolve a problem in his equipment during the EO training flight (which he eventually did after the flight). The only other problem was that the minicomputer hung up and could not be restarted late in flight 13.

Ames- At the time of the Joint Mission, the Ames PI was involved in a flight series aboard the ASO C-141 airborne IR observatory, and he delegated essentially complete responsibility for the NASA/ESA experiment to another member of the Ames astronomy group. This person flew with the experiment on the telescope during flights 2 and 15 and was aboard doing noise checks on the unmounted experiment during flights 4 and 10. (The PI was also aboard during flights 2 and 15.)

This experiment encountered ground-loop and microphonics problems. The former were resolved, and the latter were reduced but not completely resolved. The PI left the troubleshooting to his assistant. These problems were apparent during the EO training flight (2, for this experiment only); thus, the experiment was not fully operational at the start of the mission.

JPL- The PI from JPL was the nominal PI (assigned by NASA) for the JPL, Alaska, and Colorado experiment group. However, the Alaska and Colorado experiments were developed completely independently from JPL's, and they are considered separately.

The JPL PI was aboard all nonconstrained flights except flight 11 when he took a component back to the manufacturer for repair. During the flights, he actively participated in experiment operation. In addition, his knowledge of star fields enabled the several PIs to take advantage of some targets of opportunity.

The JPL experiment was not adequately prepared. Final selection of the experiments for the mission came too late for proper development of an experiment with this degree of sophistication. Critical components were at the state-of-the-art stage of development: they had been tested insufficiently on the ground and not at all in flight environments. A central component, the UV TAOF, was not received by the PI until after flight 3, and therefore received no testing prior to flight. The experiment suffered from EMI and a high background signal. Most important, however, is the fact that the PI was never able to acquire spectral information consistently with his experiment in flight. Not even fairly bright calibration sources produced well-defined repeatable spectra.

The PI originally intended to hand guide the two 20-cm telescopes on astronomical objects. This was immediately found to be an impossible task in flight; hence, the telescopes were pointed in fixed positions until flight 10 when a stabilized mirror was introduced in front of one of the telescopes.

Colorado- The Colorado PI installed his experiment without assistance. Operation required an additional person at the guide optics. During flights 1 through 9 the experiment time-shared the University of Alaska 35-cm telescope; during flights 10 through 15, it was mounted on the JPL 20-cm telescope with stabilized mirror. Even with stabilization, it was found necessary to hand guide the mirror (with joystick) on astronomical objects. The experiment was removed before flight 16. The majority of targets guided on were targets of opportunity, which the PI selected from the star field available along the flight path. The PI selected the star, put the guide optics on it, and then turned over guiding to an assistant. He collected data from as many as 10 different objects during a single flight (14).

Because of the operational state of the Alaska telescope and associated optics, and the time-share arrangement mentioned above, the Colorado experiment was not properly optically aligned on the ground and got only 15 minutes of aligning time during the two checkout flights. The system was operated through the constrained period with poor focus and with star images much too large for the slit. Optical efficiency and alignment were much improved with the switch to the JPL 20-cm telescope on flight 10.

Aside from being coupled to a poor optical system through the first part of the mission, the only problem experienced by this experiment was environmental. A thermally activated relay turned its computer off when the temperature exceeded 80° F, which happened on several flights. The PI merely waited for it to cool down sufficiently (approximately 5 to 15 minutes) then turned it on again.

Only the optical problems, which were actually those of the University of Alaska, kept this experiment from being operational at the start of the mission. A loose circuit board in the display component prevented certain display capabilities on flights 1 through 9, but this problem was peripheral and in no way hindered proper data collection.

Alaska- Two co-PIs were associated with this experiment. Generally one or the other flew with the experiment. Both were aboard on flight 10, and both participated actively in experiment operation. Operation was most convenient with two persons, so a second operator (sometimes more) was also aboard.

This experiment was not operated as a unit until its assembly aboard the CV-990. The spectrometer and associated data-handling electronics had been operated, but had never been used with the telescope and stabilized mirror. Considerable difficulties were encountered in integrating the optical system and making it fully operational. After several unsuccessful attempts to achieve optical alignment, the Colorado PI found that the primary telescope mirror was not rigidly mounted in the telescope structure. Fixing the position of this optical element was of considerable aid in achieving a permanent alignment.

This experiment could be operated in two modes: looking upward through a 65° window with only a plane mirror in front of the spectrometer slit, and looking out a 14° window through the telescope and stabilized mirror. The first mode was used most of the time and was relatively trouble free; the second mode involved the boresight problems discussed earlier.

The only major problem was a tape recorder malfunction. During the first two flights, the associated computer kept dropping out. The problem was partially analyzed by the PI in flight 3 after the tape recorder had caused components in the computer to fail. The tape recorder was removed from the aircraft and returned to the mission for flight 10. Computer problems were analyzed and repaired by a technician on the ground following the flight. All other problems were related to the telescope optics.

This experiment was not fully operational at the start of the mission. A technician worked on the guide optics during the first two flights. The lack of an accurate boresight led to guiding difficulties throughout the mission.

TABLE B-30.- FLIGHT EXPERIENCE DURING THE SIMULATION PERIOD

Experiment: Queen Mary College

Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
5P*				x	Light pipe shifted during takeoff		x					x						Reseat
					ADDAS Fourier transform program has bugs	x						x						Debug as time allows; no downlink copy for PI
					Mirror drive sticks		x	?					x					EO frees
					Digital voltmeter malfunctions		x					x						Repair after flight (replace batteries)
					Noise on most interferograms		x			x					x			Difficult to transform Problem undiagnosed
					Dewar pressure rising	x	x					x						Check pump; OK so live with. Degrades data
6P				x	Light pipe shifted during takeoff		x					x						Reseat
					ADDAS Fourier transform program has bugs		x					x						Same as in flight 5
					Mirror drive sticks (twice)		x	?					x					EO frees
					Break off part of liquid He transfer device during transfer following flight			x				x						Resolder next day (poor job according to PI) 20 min
					Noise on most interferograms		x			x						x		Difficult to transform Problem undiagnosed

TABLE B-30.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: Queen Mary College (concluded)																		
7S**				x	Mirror drive sticks occasionally		x	?					x					EO frees each time
					Noise on most interferograms		x			x						x		Problem not diagnosed
8S				x	Stripchart malfunctions		x					x						Off-duty EO works on in flight but does not fix
					EMI		x			x						x		Problem finally diagnosed. Live with
9P				x	Stripchart not operational		x					x						Backup New Mexico recorder substituted but would not advance chart properly. After Venus leg a second substitute recorder was tried, resulting, inexplicably, in inability to run ADDAS program
					No real-time Fourier transforms	x						x						ADDAS problem
					EMI		x			x						x		Live with

TABLE B-30.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Ac ion/comments
Experiment: Southampton																		
6P				x	TV down after takeoff		x				x	x						Reseat multiple-pin connector
					No power to 180° FOV zenith camera			x									x	EO forgot to turn on
7S				x	Tape recorder running at wrong speed			x						x				EO set up incorrectly; corrected after ~1 hr
					180° FOV zenith camera stops			x									x	Repair film advance after flight
					TV down after takeoff		x				x	x						Reseat multiple-pin connector
8S				x	TV down after takeoff		x				x	x						Reseat multiple-pin connector
9P				x	TV down after takeoff		x				x	x						Reseat multiple-pin connector
Experiment: New Mexico																		
5P				x	35-mm film not advancing completely (noted in development)		x						x					PI requests battery change
7S				x	Stripchart runs out of ink		x	?					x					EO started to refill, but could not finish before landing
8S				x	Stripchart malfunctions		x					x						Use spare

TABLE B-30.- Continued

Experiment: Meudon/Groningen																		
Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
5P				x	Frost on mylar	x					x	x						Degrades data
					Little guide success on S-Ceph		x				x				x			Data lost on this target
					Noise with shortest wavelength filter in is 5-7 times greater than other channels		x					x						Degrades data
6P				x	Guide on S-Ceph initially poor						x		x					Turbulent air; dim star
					Power supply goes out					x		x						Fuses blow when converter fails; obtain fuses from local vendor (not in supply)
7P				x	Frost on mylar	x							?					Live with; degrades data
					Signal level low		x				?							Check reference phase and signal channel connections; live with
					Detector temperature high		x					x						Degrades data; reason not determined
					Poor guide on NGC 7000						x			x				Turbulent air; weak source

TABLE B-30.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: Ames																		
8P				x	Inadequate guide technique		x								x			Learn technique; data loss on Venus
					Low sensitivity		x							x				Give up tracking about 1/2 way thru IRC 10216 leg
					Slight frost on mylar window	x						x						Degrades data
					Excessive aircraft roll	x					x		?					Off target frequently on Venus and α Herculis
9P				x	Frost on mylar window	x					x	x						Degrades data
					Excessive aircraft roll	x					x		?					Off target frequently
Experiment: JPL																		
5P				x	TAOF operation poor; erratic, low sensitivity and EMI		x										?	Adjust to best of ability
7S				x	Frost on window	x							?					Use heat gun to dispel
					TAOF operation poor; low sensitivity and EMI		x										?	Same signal with black cloth over telescope
					Cannot identify star field			x				x						Get aid from another EO
8P				x	TAOF operation poor; low sensitivity and EMI		x										?	Adjust to best of ability

TABLE B-30.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: JPL (concluded)																		
9P				x	TAOF high background count		x										?	Degrades data badly
					X-Y recorder not operating reliably		x					x						Use Colorado strip-chart with occasional X-Y plot
Experiment: Colorado																		
5P				x	Computer locks up		x	?									x	Reload program; doesn't solve. Check out on ground
					Optics not boresighted		x									x		Scan for object with star tracker; eventually acquire
					Frost on ~1/2 window; Venus leg	x					x	x						Degrades data, but no data in any case
6S				x	Slow acquiring Venus			x								x		Forgot to turn on high voltage to star tracker
					No oscilloscope display		x						x					Went out before flight; leaves EO in dark on experiment operation; find blown fuse after flight
					Computer will not write on stripchart (just after landing)		x	?				x						Check with PI after flight

TABLE B-30.- Continued

Experiment: Colorado (concluded)																		
Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
7S				x	Computer will not write on tape		x						x					Reload program
					Spectrometer sweep stalls 3 times		x						?					Turn off then on; restarts it. Clears itself eventually (on ground next day)
8P				x	Computer writing Z's on teletype		x					x						Hit computer (standard cure recommended by PI)
					Difficulty acquiring Venus		x						x					Lack of boresight and bright sky
					Computer locks up on Venus		x						x					Reload program
					Star tracker has low sensitivity		x									x		Little Spica data; live with
				x	Computer locks up on Spica (α Vir)		x						x					Reload program (star tracker too insensitive as well, so no data)
					Spectrometer sweep stalls		x						?					Turn off, then on; restarts it

TABLE B-30.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: Alaska																		
5P				x	Frost on window, Venus leg	x					x	x						Degrades data badly
					System tape recorder out 5 flights		x					x						Live with
					No data collection until 3 hr into flight			x						x				EO has other preoccupations
6S				x	Computer will not print out on stripchart		x					x						Check with PI; EO wires power to deactivated A/D converter after flight
					Star tracker high voltage not on			x							x			EO forgot through most of Venus leg
					Gain setting too low during entire flight			x				x						Data degraded; S/N misjudged by EO
7S				x	Failed to guide on τ-Scorpii		x										x	Star tracker lacks sensitivity
					Difficult time acquiring Venus		x							x				Poor boresight; aid from primary EO
					Frost on window for ~2 hr	x					x	x						Degrades data

TABLE B-30.- Concluded

Experiment: Alaska (concluded)																		
Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
8P				x	Spectrometer/computer interface nonoperative at shutdown (end of flight)		x					x						Discover open circuit breaker next day; reset
9P				x	Difficulties acquiring Venus		x							x				Poor boresight; bright sky
					Frost on window	x						x						Use heat gun

*P - Primary experiment
**S - Secondary experiment

TABLE B-31.- FLIGHT EXPERIENCE DURING PI OPERATION

Experiment: Queen Mary College

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
1	x			x	Trouble transferring LHe before flight; slow to achieve proper detector temperature			x					x					
					Light chopper erratic		x						x					Fix in flight
					EMI (all flights)					x				x				Not analyzed until flight 9
					Stripchart malfunctions		x					x						Replace after flight
					Pressure up in vacuum system		x								?			Suspect leak in pumping system. Check on ground after flight and replace vacuum pump
					No ADDAS Fourier transforms	x						x						Program still has bugs
					Transfer of LN_2 to cold black body does not work	x						x						Degrades data slightly Repair after flight
2	x			x	Chopper wheel erratic		x						x					Fix in flight
					Dewar develops ice plug after flight; explodes		x	?					x					Return to factory for repair; obtain backup from home
					No ADDAS Fourier transforms	x						x						Program still has bugs

TABLE B-31.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Enviroment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: Queen Mary College (continued)																		
3	x			x	Low signal while EO operated		?	?										Data degraded; not understood
					LN_2 transfer pressure gauge stuck	x						x						Repair after flight
					No ADDAS Fourier transforms	x						x						Program still has bugs
4					Not aboard													
10				x	Frequency-dependent EMI (some communication channels, not others)		x			x				x				Covering detector with aluminum reduces EMI, but does not eliminate it
					Thermocouple amplifiers short out		x						x					Repair after flight
					Frequent troubles with chopper during flights 1 through 9		x											Replace with better designed chopper for flight 10
11				x	77 K black body warms some	x						x						Trouble transferring LN_2
					EMI persists		x			x				x				Double screen (aluminum sheet inside copper screen) does not solve; lower preamp gain after flight

TABLE B-31.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: Queen Mary College (continued)																		
12				x	EMI persists at reduced level		x			x				x				Aluminum only as shield
					Microphonic noise		x				x	x						Restrain dewar motion with wire; reduces noise
					Run out of LN_2 ~2/3 through flight	x						x						Degrades data
					Lose transfer pressure in LN_2 system	x						x						Seat transfer tube in dewar more tightly with C clamps
13				x	One (of three just added) thermocouple amplifiers out		x					x						Don't understand; degrades data. Repair on ground
					EMI persists at reduced level		x			x				x				PI continues experimenting with shielding
					No real-time Fourier transforms	x						x						Program down; ADDAS up but without this program
14				x	Chopper giving d.c. signal		x					x						Realign slightly in flight
					Lock-in amplifier erratic		x						x					Locate loose reference cable

TABLE B-31.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: Queen Mary College (concluded)																		
14					Transient noise spikes		x						x					Shifts in reference phase; amp. overloading (?); live with
					EMI persists		x			x				x				Same screening as flight 13
15				x	EMI persists		x			x					x			Same screening as flight 13
					Chopper giving d.c. signal		x					x						Realign slightly in flight
					Run out of LHe; turn experiment off						?				x			Higher usage rate caused by two pump off periods for Tucson landing/takeoff
16				x	EMI persists		x			x			x					Same screening as flight 13
Experiment: Southampton																		
1	x			x	TV camera malfunction		x					x						Reseat loose electrical connector
					Lock-in amplifier erratic operation	x								?				Repair after flight
					Frost on TV window	x												Clear with heat gun

TABLE B-31.- Continued

Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
Experiment: Southampton (continued)																		
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
2	x			x	Frost on 180° FOV window	x									?			Not noted until camera removed after flight Fix on the ground
					Sky too bright during Moon track						x							Live with; degrades data
3	x			x	TV camera malfunction		x					x						Reseat loose electrical connector
4	x			x	Not aboard													
10				x	Photometer noise up by X10		x					x						Degrades data; repair on ground
					180° FOV camera film will not advance		x								?			Repair on ground
11				x	No photometer on flight		x										x	Had not been repaired
					No 180° FOV camera on flight		x										x	Had not been repaired
					Edges of TV out of focus		x					x						Degrades data; focus ground
14				x	Bright sky due to Moon						x			x				TV off 80 min; too bright
15				x	Sky too bright whole flight						x				x			Turn on only last 1/3 of flight Data degraded

TABLE B-31.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: Southampton (concluded)																		
15					No 180° FOV camera			x									x	Experimenter's choice
16					Not aboard													
Experiment: New Mexico																		
1	x			x	35-mm film transport jams		x						x					Replace with borrowed unit beginning flight 3
					Interference on 16-mm image intensifier						?		?					Do some rewiring; did not repeat on subsequent flights
2	x			x	Hand operate 35-mm camera		x					x						Not able to repair film transport
					Blown camera timer fuse		x					x						Replace in flight
3	x			x	Loose power plug		x					x						Located and reseated by EO
					EO cannot focus 35-mm system			x				x						PI does focus
					16-mm drive erratic (twice)		x						?					PI coaxes into operation
4	x			x	No 16-mm 2/3 of flight						x				x			Too bright on left side
					Eastern sky too bright for 35-mm and photometer						x	x						Data degraded

TABLE B-31.- Continued

Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
Experiment: New Mexico (concluded)																		
10				x	35-mm camera won't start		x					x						Coax into operation
					35-mm five-pulse channel on stripchart erratic		x						x					Get going eventually
13				x	35-mm five-pulse channel on stripchart malfunctions		x					x						Put on backup strip-chart
14				x	Bright sky due to Moon						x			x				16-mm system off 80 min
15,16					Not aboard; sky to bright													
Experiment: Meudon/Groningen																		
1	x			x	First target not acquired			x									x	Did not recognize star field
					Aerodynamic buffeting of telescope						x		?					No immediate fix
					Vacuum pump shutting off		x					x						Move thermal relay to cooler environment
					IR signal low		x					x						Degraded data; no analysis
2	x			x	Ames used telescope													

TABLE B-31.- Continued

Experiment: Meudon/Groningen (continued)																		
Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
3	x			x	Telescope balance poor		x						?					Degrades data; technician improved during flight
					Two (of four) filters could not be positioned correctly		x							x				PI could not repair in flight, does so on ground
					Telescope guide erratic		x				x			?				Degrades data; live with; install 2-mil mylar cover flight 4
					Failed to acquire M-17		x	x									x	Total loss of data on this target; PI guiding (against rules)
					Only partially successful guide on ρ-Oph						x			?				Data degraded; again PI guiding
4	x				Mylar window (new this flight) frosts over	x					x			?				Data badly degraded
10				x	Telescope buffeting						x		?					Mylar window out for telescope calibration; degrades data
					Difficulty guiding on W-51; rough ride plus did not recognize star field			x			x				x			Inexperienced guide operator

TABLE B-31.- Continued

Experiment: Meudon/Groningen (concluded)																		
Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
11				x	Guide on NGC 7000 difficult						x		x					Rough flight environment
					Mylar telescope cover bulges out	x						x						Effect uncertain; only 1-mil mylar
12				x	Frost on mylar	x						x						Increase cabin air flow
					Mylar telescope cover bulges out	x						x						Effect uncertain; switch back to 2-mil mylar
					Guide difficulties NGC 7000; rough and scattered cirrus						x		x					Live with
13				x	Computer program hangs up		x							x				Repair on ground
14				x	Guide difficulties on S-131 and ρ-Oph						x			x				Rough flight path; live with
15					Only one Meudon telescope operator aboard for Ames													

TABLE B-31.- Continued

Experiment: Ames

Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
2	x			x	Telescope guiding erratic						x		?					EO training flight Aerodynamic buffeting
					High detector noise level		x							?				Degrades data; check grounding
					Stripchart inking stops		x					x						Got going in few minutes
4	x				Zero test time				x								x	Change in flight plan
10	x				System still noisy		x					x						Analyze further on ground
11-14					Not aboard													
15				x	System microphonic		x					?						Degrades data
					Guide difficulties						x			x				Live with; flight path turbulent; inexperienced operators
16					Not aboard													

TABLE B-31.- Continued

Experiment: JPL																		
Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
1	x			x	Hand guiding idea fails			x									x	Abandon guiding on astronomical targets by hand
					Cables in operator's way		x					x						Move after flight
					No UV TAOF												x	Not delivered from factory
2	x			x	Frost on window	x							x					Clear with heat gun
					No UV TAOF												x	Not delivered from factory
3	x			x	High background on visible TAOF signal		x					?						Use UV PMT* (just acquired) on visual TAOF
					No spectral data acquired		x										x	Problem not analyzed, turn off 2/3 through flight
4	x			x	Frost on window	x												Degrades data; clear with heat gun
10				x	UV TAOF lacks sensitivity		x										x	Do not understand
					UV TAOF has EMI		x			x								Degrades data

*Photomultiplier tube.

TABLE B-31.- Continued

Flight no.	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	Data lost, percent: None	<25	<50	>50	>75	Total	Action/comments
Experiment: JPL (continued)																		
10					Visual TAOF has high background		x											Use after UV TAOF; degrades data
					Visual TAOF has EMI		x			x								Degrades data
11				x	No UV TAOF instrument		x										x	PMT failed preflight; taken to factory by PI
					Visual TAOF high background still		x								?			Degrades data badly
12				x	EMI persists; turn off visual TAOF ~2/3 way through flight		x							x				rf on all power lines to experiment
					No UV TAOF			x									x	UV PMT used with visual TAOF to reduce back-ground; experimenter's choice
13				x	Visual TAOF high back-ground and low sensitivity		x										?	PI doesn't understand; only small effort to correct
					UV TAOF low sensitivity		x										?	Mounted on telescope only 10 min of flight
					EMI on UV TAOF		x			x		?						Degrades data

TABLE B-31.- Continued

Experiment: JPL (concluded)																		
Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
14				x	Lose visual TAOF ADDAS interface					x				x				Caused by power transient; patch equivalent UV box into system
					Visual TAOF high background and low sensitivity		x								x			Don't understand; turn off ~1/2 through flight
					No UV TAOF operation		x										x	Experimenters choice
					EMI on visual TAOF		x			x		?						Degrades data
					Stabilized mirror control erratic	x							x					Change after flight
15				x	No UV TAOF; problems persist		x										x	Use UV PMT on visual system
					Stabilized mirror control erratic	x							x					Adjust in flight by technician
16				x	No visual TAOF													Experimenter's choice
					UV TAOF low sensitivity		x							x				Improved but still low
Experiment: Colorado																		
1	x			x	Zero minutes optic alignment time		x										x	Alaska PI worked on guide system entire flight
2	x			x	Only 15-min optical alignment time		x									?		Poor, but live with

TABLE B-31.- Continued

Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
Experiment: Colorado (continued)																		
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
2					Thermal relay shuts down computer						x	x						Let cool; turn on again
3	x			x	Frost on window	x						x						Clear with heat gun
					System not boresighted		x	x					x					EO improves during flight
					Nothing bright enough to guide on after Venus leg		x										x	Secure ~2/3 through flight
4	x			x	Computer nonoperational		x	?									x	Operated by JPL PI; problem not analyzed
10				x	Window fogging	x						x						Clear with heat gun
					Computer down twice due to high ambient temperature		x				x		x					Thermal relay shuts off; let cool; turn on again
12				x	Guiding difficult ~1/2 flight						x			x				Rough flight environment
14				x	Computer knocked out					x								Power transient; up again shortly
15				x	Stabilized mirror control rough	x						x						Ames technician adjusts in flight
16					Not aboard													

TABLE B-31.- Continued

Experiment: Alaska																		
Flight no.	Flight type				Problem description	Problem cause						Data lost, percent						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Operator	Aircraft	A/C equipment	Environment	None	<25	<50	>50	>75	Total	
1	x			x	Computer down frequently first 1/3 flight		x						x					Problem not analyzed
					Star tracker not aligned		x					x						Work on during flight
					Purging N_2 gas stopped	x						x						Ames technician gets going again
2	x			x	Computer down frequently first hour		x						x					Problem not analyzed
					Frost on window (~20%)	x							x					Degrades data
					Star tracker will not track objects dimmer than Venus		x						?					Live with
3	x			x	No Venus data; telescope acquired, but not on spectrometer inlet slit		x	x									x	Total this target
					Computer locks up repeatedly		x										x	EO gives up ~2/3 through flight; PI finds will work without tape recorder; solve problem on ground

TABLE B-31.- Concluded

Experiment: Alaska (concluded)

Flight no.	Flight type: Check	Flight type: Calibration	Flight type: Transit	Flight type: Data	Problem description	Problem cause: GFE	Problem cause: Experiment	Problem cause: Operator	Problem cause: Aircraft	Problem cause: A/C equipment	Problem cause: Environment	Data lost, percent: None	Data lost, percent: <25	Data lost, percent: <50	Data lost, percent: >50	Data lost, percent: >75	Data lost, percent: Total	Action/comments
4	x			x	Window fogs badly	x								?				Degrades data badly
					Boresight poor; only 15 min on Venus		x	?								x		Readjust partially in flight
13				x	Spectrometer operation erratic; cam drive too cold		x				x		x					Heat mechanism with heat gun
14				x	Not ready for prime target opportunity			x							x			Over 50% loss of data this target
15				x	Clouds ruin low-level data legs						x		x					Live with
					Object acquisition slow		x				x				x			Sky too bright for method; data lost on Venus
16				x	Object acquisition slow		x				x			x				Sky too bright for method; data lost on Venus

TOOLS AND TOOL USAGE

A work station built into a standard rack was provided for EO use during the confined portion of the Joint Mission (fig. B-37). The work station rack was installed in the rear of the aircraft on the right side in the same location as the FMI rack (which was removed for the confined week). The EOs' working surface was exposed by lifting a lid containing several of the more commonly used tools. Additional tools plus spare parts and miscellaneous supplies were stored in two tool drawers (bottom right), a storage bin (bottom left), and a compartmented cabinet (middle right). The total weight of these items was 64 lb (29 kg). Test equipment available at the station included a waveform generator (mounted on the forward side of the rack and not visible in the figure), a microammeter (upper right), and a portable oscilloscope and digital voltmeter (mounted adjacent the rack). The total rack weight was 271 lb (123 kg); the oscilloscope weighed 21 lb (9.5 kg) and the voltmeter 1 lb (0.45 kg).

Tables B-32 and B-33 list all work station tools and spare parts, together with their average usage during the mission. The tool complement was developed in consultation with the PIs. Interested personnel from NASA-Marshall Space Flight Center had developed an initial tool list. This list was then circulated to each PI, who indicated his need for each tool and added those he felt necessary. Requests from all the PIs were combined to compile the list shown in the tables.

In general, the work station was well received, and good use was made of standard tools for routine maintenance and repair. These included small wrenches, screwdrivers, pliers and cutters, and a soldering iron. Metric hand tools were provided for the parts of the Meudon/Groningen experiment requiring them, but they were not needed. Tools and equipment provided for more major repairs were not needed during the confined week.

The EOs used the work surface when repair of components necessitated their removal from the experiment rack. The EOs also could gather there to observe work being performed on items of mutual interest. However, the EOs often found it more expedient and efficient to probe installed experiment components with test equipment at the rack than to remove suspected components for troubleshooting at the work station. They also found the work station microammeter too sensitive for their applications and preferred to use their own portable instruments.

Certain hand tools were kept at each experiment for the entire confined week. These tools were peculiar to the particular experiment, or needed on a continual basis for experiment operation or adjustment. Examples of the experiment-peculiar tools are a hex key driver and a screwdriver, both made extra long, and a 3/8-in. ratchet drive with a 10-in. extension and a 70-mm socket, all used to remove the Groningen or Ames dewar from the Meudon telescope. Table B-34 lists these tools for each experiment.

Each PI was allowed one large box of tools, supplies, and spares considered most useful for the EOs during the simulation week (table B-35).

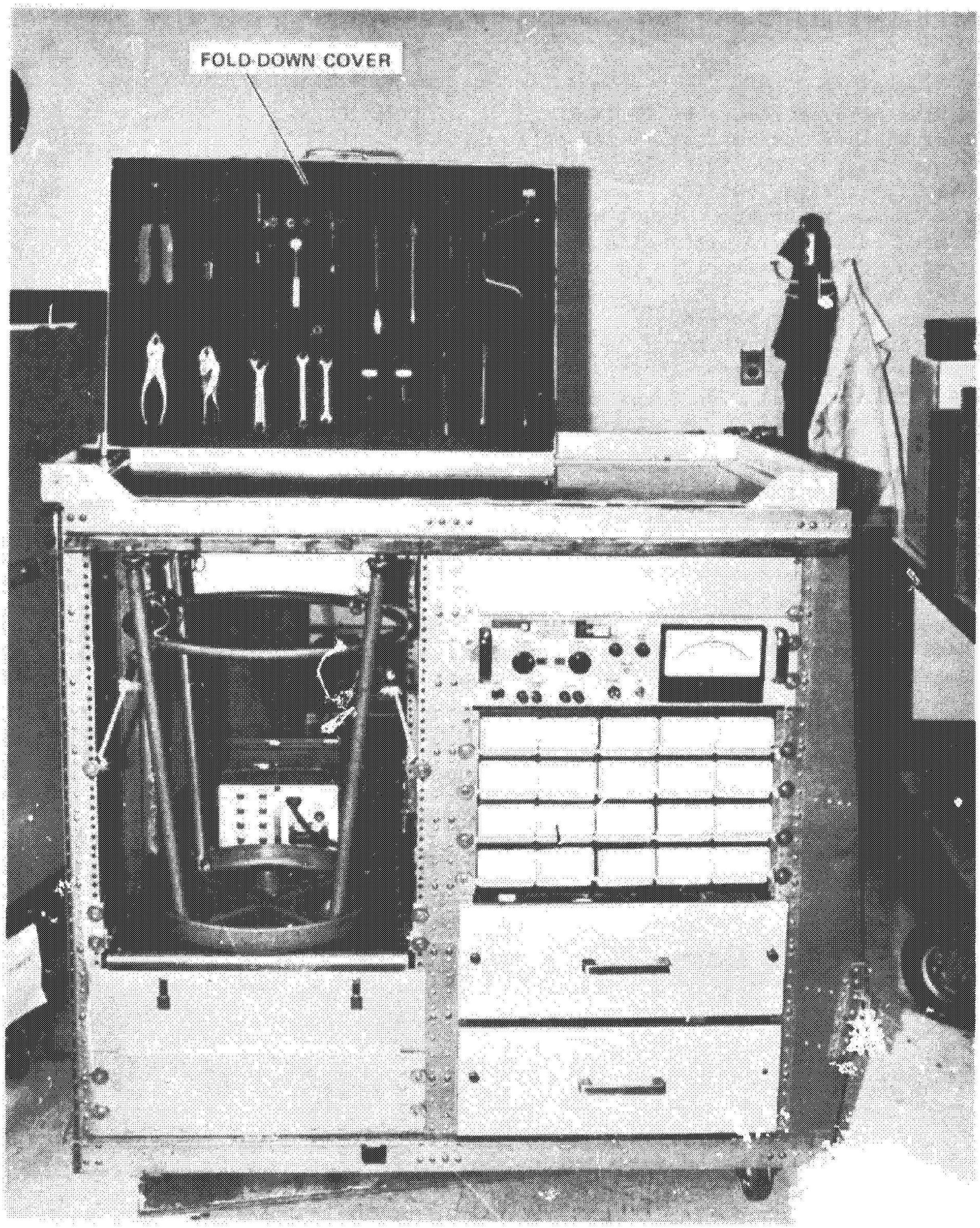


Figure B-37.- Experiment operators' work area.

TABLE B-32.- U.S. STANDARD HAND TOOLS INSTALLED IN WORK STATION LID

Item	Quantity	Used		No. of uses
		Yes	No	
Medium blade screwdriver (9 in.)	1	X		9
Medium blade screwdriver (4-1/2 in.)	1	X		10
Heavy blade screwdriver (10 in.)	1	X		4
Phillips screwdriver (#2)	1	X		5
1/4 in. drive socket ratchet wrench	1	X		2
1/4 in. drive 2 in. extension	1	X		1
1/4 in. drive screwdriver (6 in.)	1		X	
1/4 in. 6-point socket	1		X	
3/8 in. 12-point socket	1	X		1
7/16 in. 12-point socket	1		X	
Torque-set screwdriver (8 in.)	1	X		1
#4 torque-set bit	1	X		3
#6 torque-set bit	1		X	
#8 torque-set bit	1		X	
#10 torque-set bit	2	X		1
1/4 in. torque-set bit	1		X	
#1 Phillips head bit	1		X	
#2 Phillips head bit	1		X	
Adjustable crescent wrench (6 in.)	1	X		6
Open-end wrench (3/8 in.)	1		X	
Open-end wrench (7/16 in.)	1	X		1
Combination-end wrench (3/8 in.)	1		X	
Small wire stripper and terminal crimper	1	X		2
1/4 in. drive speed wrench	1		X	
Miniature side cutter plier (Dykes) (5 in.)	1	X		5
Miniature needle nose plier (4-1/2 in.)	1	X		7
Miniature end cutter plier (4-1/2 in.)	1	X		2
Common plier (6 in.)	1	X		1
Miniature vise grip (5 in.)	1	X		6

TABLE B-33.- WORK STATION TOOLS AND EQUIPMENT

Item	Quantity	Used		No. of uses
		Yes	No	
Hand tools - Metric				
Open-end wrench set	6 pieces		X	
Box-end wrench set	6 pieces		X	
Combination-end ignition wrench set	9 pieces		X	
1/4 in. drive socket set with accessories	20 pieces		X	
Nut driver set	7 pieces		X	
Hex key wrench set	10 pieces		X	
Hand tools - British standard				
Whitworth spanners (wrenches)	4		X	
Hand tools - U.S. standard				
Combination-end wrench set	15 pieces		X	
Open-end wrench set	3 pieces	X		2
Ignition wrench set	4 pieces		X	
1/4 in. drive socket set with accessories	14 pieces	X		2
3/8 in. drive socket set with accessories	20 pieces		X	
Nut driver set	9 pieces		X	
Hex key wrench set	10 pieces	X		1
Hex key ball driver set	12 pieces		X	
Adjustable end wrenches (6 in., 10 in.)	2		X	
Vise grip pliers (5 in., 8 in.)	2	X		6
Needle nose pliers (5 in., 7 in.)	2	X		9
Curved needle nose plier	1		X	
Side cutter pliers (4-1/2 in., 7-1/2 in.)	2	X		6
End cutter plier (4 in.)	1	X		2
Round-jay needle nose plier (4 in.)	1		X	
Channel-lock plier (7 in.)	1		X	
Common plier (6 in.)	1	X		1
Wide-tip blade screwdrivers (13 in., 10 in., 7-1/2 in.)	3	X		4
Narrow-tip blade screwdrivers (10 in., 6 in., 4 in. stubby)	3	X		11
Phillips screwdrivers (#1, #2)	2	X		5
Reed-Prince screwdriver (#2)	1		X	
Offset screwdrivers				
Blade	1		X	
Phillips	1		X	
Jeweler's screwdriver set (blade)	6 pieces	X		10
Torque-head driver (8 in. and stubby)	2	X		3
Torque-head bits	12 pieces	X		3
1/4 in. drive torque-head bit adapter	1		X	
Phillips head bits	2		X	
Half-round files (12 in., 8 in.,) (2 coarse, 2 fine)	4		X	

TABLE B-33.- Continued

Item	Quantity	Used		No. of uses
		Yes	No	
Hand tools - U.S. standard (continued)				
Flat files (12 in., 10 in., 8 in.) (coarse, fine, extra-fine)	3		X	
Round-handle needle file set	12 pieces		X	
Small soldering iron	1	X		3
Small soldering iron tips	3		X	
Small wire stripper and terminal crimper	1	X		2
Medium weight ball-pein hammer	1		X	
1/4 in. cordless electric drill with charger	1	X		1
Metal twist drill set (#1 to #60)	60 pieces	X		2
Hack saw with high-speed blade	1		X	
Extra high-speed hack saw blades	2		X	
Scissors	1	X		19
Compound action left-cut metal shears	1		X	
Adjustable ratchet tap wrench	1		X	
Die set (4-48 to 5/16-24)	11 pieces		X	
Needle nose tweezer	1	X		2
Curved-tip needle nose tweezer	1		X	
Mechanical pick-up fingers	1		X	
X-acto knife (curved blade)	1	X		3
X-acto knife pointed blade refills	5 pieces		X	
Inspection mirror	1	X		4
Flat mirror	1		X	
Glass cutter	1		X	
3-inch C clamp	3		X	
2-1/4-inch C clamp	3		X	
Scriber	1		X	
Drift punches (1/8 in. and 3/8 in. × 8 in.)	2		X	
Brass connectors for 1/4 in. tubing	4		X	
Rubber tubing clamps (to 9/16 in.)	12		X	
Test equipment				
Microammeter	1		X	
Function generator	1		X	
Digital voltmeter	1		X	
Oscilloscope	1	X		1
BNC test cables (3 ft long)	3		X	
Patch cords (alligator clips)	12 pieces	X		2
Maintenance and servicing equipment				
Tin alloy solder	1 roll		X	
Adhesive and sealing compound	2 tubes		X	
Plastic electrical tape	1 roll	X		2
Silicone rubber (RTV 108)	1 tube		X	
Extra fast setting epoxy	12 packets	X		2
3/4 in. masking tape	1 roll	X		8

TABLE B-33.- Concluded

Item	Quantity	Used		No. of uses
		Yes	No	
Maintenance and servicing equipment (contd.)				
1 in. masking tape	1 roll	X		5
4 in. plastic cable ties	50	X		4
7 in. plastic cable ties	50		X	
12 in. plastic cable ties	100		X	
3/4 in. cellulose (Scotch) tape	2 rolls		X	
Dewar emergency filling kit	1		X	
Desoldering tool	1		X	
Spare/replacement parts				
Fuses (10 each 1/2, 1, 1-1/2, 2, 3, 5, 10, and 15A)	80 pieces	X		1
Batteries (1-1/2V D-size)	24	X		1
Batteries (1-1/2V AA-size)	24		X	
Miscellaneous				
Utility wipes	1 box	X		4
Writing paper	2 pads		X	
Mechanical pencils	12	X		3
Ballpoint pens	3	X		2
12 in. plastic ruler	2		X	
Workstool	1	X		2
Paper clips	1 box	X		few

TABLE B-34.- STANDARD OPERATING AND EXPERIMENT-PECULIAR TOOLS

Queen Mary College	
(4)	Long hex keys (for removing top of the chopper box and top of the helix drive when it becamed jammed)
(1)	Ratchet wrench and socket for removing dewar
(1)	Medium blade tip screwdriver (for removing tops of the black bodies)
(1)	Neoprene tube (3 feet) to siphon black body
	Strands from multistrand wire (for cleaning recorder pens)
(1)	Helium-filled balloon (for venting the dewar with helium)
(1)	Syringe (for filling ink bottles)
(1)	Flashlight
(1)	Felt pen (for writing on chart recorders)
	Various size fuses
Southampton	
(1)	1/16-in. hex key screwdriver (for truing up the photometer filter wheel)
(1)	1/8-in. hex key wrench (for locking the focusing lens)
(1)	Phillips screwdriver (for removing the top of the preamplifier to change batteries)
(1)	Flashlight
(1)	Felt pen (for writing on chart recorders)
(1)	Syringe (for filling ink bottles)
New Mexico	
	Scissors (for cutting film and chart paper)
Meudon/Groningen	
(1)	3/8-in. ratchet drive with 10-in. extension and 70-mm socket
(1)	16-in. blade screwdriver
(1)	18-in. hex key screwdriver (Above three items were required for dewar removal)
(1)	Small blade screwdriver (for connecting electrical plugs to the dewar)
Ames	
(1)	Spare preamplifier
(1)	Tube vacuum grease
(1)	Tape measure
	Spare preamplifier power leads
(3)	Short BNC cables

TABLE B-34.- Concluded

Ames (continued)	
(1)	Puller
(1)	Package Q-tips
(1)	Package emery paper
(1)	Pen cleaning kit for recorder (includes ink, wire, syringe, slide wire cleaner)
	Spare assorted O-rings
	Dewar filling equipment (jug, funnel, shield measuring stick, warming rod)
(5)	Rolls of paper for recorder
(1)	Spare motor power cable
(1)	Extension cord
(1)	Small multimeter
(1)	Spool Nichrome wire
	Pump oil
	Alcohol
	Assorted weights to balance telescope
JPL	
	Extra X-Y recorder paper
(1)	3/8-in. socket and ratchet drive
(1)	Set flexible shaft hex key screwdrivers
Colorado	
(1)	Hex key wrench (for 1/4-28 screws)
Alaska	
(1)	Hex key wrench (for use on spectrometer)
(1)	Very small Bristol wrench (for use in changing pens on chart recorder – comes with each new pen)
	Spare pens for chart recorder

TABLE B-35.- STORED TOOLS AND PARTS

Queen Mary College
- Tool box #27
  - 4 stripcharts
  - Recording ink
  - Ink capsule
  - Spare ADC board
  - Spare input polarizer
  - Beam-splitter box and spares
  - Interference filters
  - Stabilized mirrors
  - Fuses
  - Funnel
  - Foam-plastic bucket
  - Q-compound, piece of BNC cable (approximately 1 m)
  - Rubber pumping pipe
  - Spare chopper motor
  - 3 balloons
  - Allen keys
  - Silicone rubber
  - 2 bias boxes
  - 4 small spanners
  - O-rings
  - 6 batteries for preamp.
  - LN_2 transfer tube
  - Spare bias resistors
  - Laser
  - Polarizer
  - Small alignment mirror
  - Second log book
  - OG super bonder
  - Ink syringe (see Southampton box)
  - Miscellaneous items

Southampton
- Box in hold
  - Video tapes (28)
  - Chart recorder rolls (8)
  - Specific electronic spares
    - Transistors
    - Integrated circuits
    - Fuses
  - Batteries (photometer) (8)
- Refrigerator
  - Nikon film (8 rolls, 35-mm)
- Rack bin
  - AVO multimeter (and leads)
  - Allens (3) specific for TV and photometers
  - 240-V soldering iron for use on rack
  - 1 set small B.A. size spanners (English electrical size)

TABLE B-35.- Continued

- Southampton (continued)
  - Rack bin (continued)
    - 2 IR filters (TV camera/photometer)
    - Photometer kit (ink, syringe, spare cartridges)
    - Spare relay for TV camera
    - Adhesive tape
    - Survival kit
      - 1 pair rubber gloves
      - 1 packet bromide tablets
      - 1 set tissues, cleaning
      - 1 jar stopcock grease
      - 1 phono mag
- Meudon/Groningen
  - Plane storage tool box #11
    - Suitcase of electronic tools (see following list for contents)
    - Tools for cryostat connection
    - Connection box (CDC/Phillips recorder)
    - Rubber bands
    - Sticking labels
    - 1 spare set of Allco pens
    - 1 spare Allco empty drum
    - Headset for video tape/voice track replay
    - 5 sets of tapes (4 video, 2 CDC, 2 Dectapes, 1 Allco chart, 1 HP-chart on 3 sets only) (one per day)
    - 6 batteries 1.5V (flashlight)
    - 4 batteries 12.6V (preamp-cell)
    - 1 spare set of tapes (1 video, 1 CDC)
    - 1 multimeter
    - 1 set of metric Allen wrenches
  - Experiment (drawer)
    - 2 Dectapes Prong 1 Prong 2 (program acquisition)
    - 2 Dectapes Sys 1 Sys 2 (relectore)
    - 3 flashlight
    - 1 reticle set (ρ Oph, M-17, NGC 7000)
  - Suitcase of electronic tools in tool box #11 (as listed by PI)
    - 1 far à sender 110-220 V
    - 1 boîte d'outillage "Facom" R.430E
    - 2 boîtes d'adaptateurs BNC
    - 1 boite de cosse
    - 1 prolongateur "suiveur de spot"
    - 1 pince à fretter
    - 1 tournevis cruciforme adaptable
    - 1 pompe à désouder
    - 1 couteau
    - 1 pince à manchonner
    - 1 pince à becs ronds
    - 3 tournevis cruciformes
    - 3 tournevis 3, 4, 5 mm

TABLE B-35.- Continued

Meudon/Groningen (continued)
- Suitcase of electronic tools in tool box #11 (continued)
  - 1 lime ronde ϕ 4 mm
  - 1 pince à sertir
  - 1 pince à becs coudés
  - 1 pince universelle
  - 1 pince coupante de 200 mm
  - 1 pince coupante de 120 mm
  - 1 pince à dénuder
  - 1 pince stripmaster
  - 1 pied à coulisse
  - 1 réglet de 300 mm
  - 1 double mètre
  - 2 pinces "brucelles"
  - 1 jeu de clés "6 pans"
- Van storage (on ground)
  - Delat 60-V supply for battery charge
  - Phillips 4-channel tape recorder
  - 110/220-V transformer
  - 4 cassettes (cartridge)
  - Pump oil
  - Alignment set for main telescope
- Other equipment (on ground)
  - Helium transport container and transfer tube and adjustable table
  - Typewriter-teletype
  - Nitrogen two-stage pump

University of Alaska
- Tool box #18
  - Brush chart paper - 12 rolls
  - Magnetic tape - 10 rolls
  - Fuses
    - TE cooler 2 amp MDX
    - Digidata P/S 2 amp
    - Tape transport 4-amp S/B
    - Brush 3-amp S/B
    - Display unit 2-amp S/B
    - NOVA 15-amp 3 AG
    - Control box 2-amp S/B
  - Rubber eyepiece guard
  - Lens tissue
  - Spacom pulse amplifier discriminator
  - Spacom H/V P/S
  - Box miscellaneous quartz lenses and nonpolarizing filters
  - Spare piece of blank
  - Extra flashlight
  - Extra 28-V lamp for panel light
  - 1 spare photomultiplier tube
  - 9 transistors

TABLE B-35.- Concluded

University of Alaska (continued)
Tool Box #18 (continued)
10[illegible] chips
Miscellaneous instruction manuals
1 wirewrap tool and battery charger
1 extender card for I/O multiplexer
1 ring stand
2 boxes of 15-amp fuses
2 boxes of 5-amp fuses
4 pic belts (FA95)
1 male-to-male BNC adaptor
2 banana jacks to BNC adaptor
Manual for Nuclear Data Enhancetron
Manual for Brush chart recorder
1 set schematics for NOVA 1200
Manual for thermoelectric cooling unit
Manual for Tektronix 4010 display unit
Assembly and setup notes for spectrometer
Manual for operating spectrometer control box
Log book for 1-m Ebert Fastie spectrometer

> Payload specialists can make significant contributions to experiment design, particularly in the area of equipment operation, if they become involved sufficiently early in the design process.

EOs believed that there were many human-engineering aspects of equipment design that they could have favorably influenced had they been involved in the experiment during the formative stages of hardware design. Even as late as the experiment-aircraft integration stage, the EOs were making suggestions for hardware and operation changes, many of which were implemented.

One ESA EO was involved early with the University of Southampton experiment. As a result, he was able to aid in the design of equipment and circuitry. This experiment operated well throughout the mission. The early involvement of the EO in development of the experiment undoubtedly was a factor in its success.

> The probability of experiment success on a Space mission should be demonstrated and confirmed well before payload integration begins. A reasonable level of risk should be accepted, but this cannot be defined if an experiment has not been proven operable in the flight configuration. In any case, the Mission Manager should have the option to deny flight approval.

One U.S. experiment in the Joint Mission payload consisted of new equipment that had not been sufficiently tested prior to installation because of schedule conflicts both internal and external to the PI's staff and organizational support. There was an obvious time constraint that prevented the timely development of the associated electronics, and the necessary familiarization of the PI and his team with the operational characteristics of the equipment. Inadequate review procedures failed to screen out this experiment and forced management to gamble on the outcome. Although much useful ASSESS information was gained, the scientific return was not satisfactory.

Another experiment consisted of a new instrument coupled to a telescope that (because of late delivery) had not been properly checked for optical alignment and stability. Experiment integration and testing were limited by time and funding. The complete electro-optic system was not assembled until the installation period at Ames. Although much was done to overcome the earlier deficiencies, the final result was reduced effectiveness of the experiment during the mission and a significant negative impact on an associated experiment that time-shared optical equipment.

> Electromagnetic compatibility (EMC) engineering should be considered a basic requirement throughout the Spacelab payload design process.

The boxes were stored in the aircraft forward cargo hold. Not all of the PIs took advantage of this contingency storage; no use of the stored equipment was observed.

SUMMARY

The following comments are similar to those on experiment equipment contained in the final report (ref. 2). Boxed statements are taken from reference 1 and represent lessons learned in the Joint Mission. A few comments have been added where appropriate.

> Early in the development of the experiment equipment, the design of individual components must be guided by the fact that each experiment will be operated as an integral part of the total payload.
>
> Minor (but time-consuming) activities, such as switching, should be automated to permit full concentration on the real experiment operation. All experiments should include displays that indicate proper operation.

Little attempt could be made by PIs during the Joint Mission to coordinate the design of their several experiments for control by a single operator due to funding limitations. As a result, the EOs were put to the additional trouble of operating experiments from physically separated control panels. The implication for Spacelab is that groups of experiments that will be operated by a single payload specialist must be coordinated early in the design process. This requirement poses an additional burden on the mission management.

Fixed sequential operations in experiments could be automated for the benefit of the payload specialist. Timers or other sequential types of switches can readily be tied to go-no-go indicators so that the operator may be made aware if some step fails to operate properly. Since the design of such switching circuits is a specialized branch of electrical technology, it would be reasonable for the management staff to aid experimenters with this portion of their equipment.

Coordination of equipment design for a group of experimenters will obviate problems of minor differences in controls, which was a source of problems on the Joint Mission. Uniform standards will be required for simple operations, such as direction of toggle-switch operation. (US standard is up-on, while the British standard is just the opposite.) A more serious problem on the Joint Mission was created by differences in keyboard layout of two separate computer interfaces on one group of experiments. These differences caused the operator to make a number of time-consuming errors.

The frequencies used by radio transmitters aboard the aircraft are listed in the CV-990 Experimenters' Handbook so that these may be avoided. Two experiments nevertheless proved very susceptible to RF pickup when transmitters were operating. Such interference commonly enters experiments through high-impedance detector circuits. PIs and EOs lost considerable time in attempting to diagnose and alleviate these situations. Significant data degradation resulted from such pickup. In another experiment, external magnetic fields caused some distortion of electron-beam images, but without serious loss of data, although data reduction completely was markedly increased.

In all three cases, the PI was unaware of the potential for trouble in his equipment, not necessarily because of unfamiliarity with EMC procedures, but because he did not foresee a problem in the aircraft environment. This experience clearly suggests the need for laboratory tests during development to simulate the EMI conditions for Spacelab, especially when high-impedance circuits or electronic imaging devices are a necessary part of the experiment.

During the mission, EMI tests and measurements were made under the direction of ESTEC personnel. PI preparations for these tests undoubtedly reduced the influence of EMI on the experiments, while on-site measurements suggested some corrective actions. Unfortunately, the effort was not begun as an integral part of experiment design, nor was it available to U.S. experimenters before payload integration.

> Although the use of off-the-shelf equipment is encouraged, some minimal standard of performance should be established to avoid the low reliability that was noticed in some minor items, such as stripchart recorders.

Stripchart recorders, as a class of equipment have consistently shown low reliability in airborne operations. However, experimenters find them convenient in examining trends in the data. Rather than discouraging their use altogether, it would be better to ensure that the operation of an experiment does not depend critically on a chart recorder. Alternately, much of the trouble could be avoided by using other recording methods, as for example, a heated stylus.

In a more sweeping indictment of recorders in general, on EO observed that each had a different procedure for loading, none of which could be done quickly and with complete assurance. He recommended that all Spacelab recorders be equipped with standard cassettes — whether for film, tape, or charts.

Another persistent cause of trouble was the loosening of electronic cards in their sockets by vibration during takeoff. The obvious remedy is to engineer better holddowns for such cards.

The implication for Spacelab is twofold: that minimum equipment performance standards should be adopted, and that all electronic equipment should be inspected by a specialist in airborne electronics who can suggest improvements in the equipment that will reduce the likelihood of problems.

With no limitation imposed on power, volume, and weight, the demands of available equipment can be quite high. For example, on the ASSESS flights the values of these quantities were as follows:

Volume: 10 m^3, total payload

Weight: 1700 kg, total payload

Power: 3 W/kg

Although these values could be reduced by state-of-the-art advances, off-the-shelf equipment used on Spacelab may still require modification to satisfy payload constraints.

A significant difference between the CV-990 as a laboratory and Spacelab will be the basic electric power available. Adequate 60-Hz power was available on the aircraft. On Spacelab, the basic power supply will be 28 V d.c. The conversion of that basic power to 60-Hz power, only to have it re-rectified to dc for use within the equipment, will be wasteful of both power and total stored energy, and could become critical. Thus, it seems clear that as much equipment as possible should be modified from its off-the-shelf configuration to permit direct utilization of the 28-V d.c. power.

Cryogenic support for experiments should be included in any general provisioning support system developed for Spacelab. On ASSESS, significant problems were encountered with experiment-provided cryogenic equipment.

Four experiments required cryogenic support in the form of 70 liters of liquid helium, 850 liters of liquid nitrogen, 6 kg ice and 6 m^3 (standard) of helium gas during the 5-day simulation. To supply a continuous dry-gas purge to one experiment, 450 liters of the liquid nitrogen was used.

Four significant problems with experiments and one with GFE occurred during the entire mission. During the checkout flight period, two dewars were damaged by ice plugs and replaced with backup units, while the GFE liquid nitrogen evaporator was flushed to remove trace-oil contamination. Malfunctioning equipment that caused the other two problems were repaired by EOs with verbal support from PIs, a leaking liquid helium evaporator that caused a partial ice blockage in one experiment, and a broken dewar insert that served as a helium-surge baffle in another.

Experiment setup times and procedures can represent a major part of experiment operation and must be considered in developing the mission timelines.

Although notable success was achieved in reducing manpower loading, none of the experiments on the Joint Mission had been refined to the point of being easy for an EO to use. Each experiment was provided with a large number of controls and adjustments. Thus, experiment operation, particularly startup

operations, required an inordinate amount of attention from the EOs. Mission timelines were affected by the inability of the EO to operate all the necessary controls on several experiments simultaneously. All recommended an increased amount of automation for basic control operations.

> Payload specialists should normally not be responsible for subsystem operation and maintenance, but should concentrate fully on payload operation.

Experience on the Joint Mission showed that EOs had little or no time during experiment operation to attend to subsystems. Furthermore, any time spent training in these tasks would have detracted from EO preparations for their assigned research duties.

Vehicle subsystems that support experiment operation — for example, CDMS or cryogenics resources — are not the province of the payload specialist, and any effort in this direction will detract from his primary assignment. The operation and maintenance of these systems should be handled by the Mission Specialist who has been trained in their use, and his backup should be one of the orbiter crew. A high level of automation will be required of these subsystems to minimize routine tasks and free the Mission Specialist for creative interaction and direct support (as required) of the research team.

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